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This month's contributors include...

ROBBANINO

SCIENCE JOURNALIST



How do illustrators create artwork of exoplanets that we can barely detect, let alone see? Rob finds out. *Page 69*

MATTHEW COX

SCIENCE WRITER



This month marks 15 years of continuous habitation of the ISS. Matthew reveals what life is like at 400km. *Page 74*

ANDREW GILHOOLEY

AMATEUR ASTRONOMER



Solar observer Andrew reveals how you can make a simple device to view the spectrum of our star for yourself. *Page 81*

PAUL MONEY

REVIEWS EDITOR



Paul takes a look back at the stalwart Orion Optics VX8 f/4.5 Newtonian in our latest *Tried & tested* review. *Page 90*

Welcome

We're reaping the rewards of missions planned long ago



At last, New Horizons has begun sending back its store of high resolution images and we are in for a treat, judging from its latest picture. The layered atmosphere and irregular surface geology this shows is strikingly beautiful and packed with science; discover more on page 13.

The probe itself is presently way beyond Pluto, streaming through the vast outer regions of the Solar System known as the Kuiper Belt. This was, up until the early 1990s, an area of which we had no observed proof. But that changed when a British astronomer, Prof Dave Jewitt, identified the first Kuiper Belt object, and in the intervening two decades thousands more have been discovered. He tells us why this region is still a mystery and what new light New Horizons will shed on it on page 32.

We have more than one ground-breaking mission exploring the Solar System – I'm talking of course of about Rosetta. With its quarry, Comet 67P, undergoing perihelion in August, the mission observed heightened activity, and on page 62 Will Gater examines the science haul that Rosetta has returned so far from the comet's close encounter with the Sun. Also see page 12 for coverage of the latest news about water on Mars.

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We're back to Earth on page 38, where we look at the striking astro imagery that can be achieved from light polluted cities with a little know-how and perseverance. Jaspal Chadha explains how his determination paid off and how he now captures delicate detail in deep-sky objects from his garden observatory in London.

Enjoy the issue!

Chris Bramley Editor

PS Next issue goes on sale 19 November

Sky at Night LOTS OF WAYS TO ENJOY THE NIGHT SKY...



TELEVISION

Find out what *The Sky at Night* team will be exploring in this month's episode on page 19



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In the magazine

NEW TO ASTRONOMY?

See *The Guide* on page 78 and our online glossary at www.skyatnightmagazine.com/dictionary

NEW HORIZONS: UNCOVERING THE KUIPER BELT

32

REGULARS

06 EYE ON THE SKY

The best images from pro observatories.

11 BULLETIN

19 WHAT'S ON

21 A PASSION FOR SPACE

With *The Sky at Night* co-presenter Maggie Aderin-Pocock.

23 JON CULSHAW

Jon's off-world travelogue continues.

25 INTERACTIVE

26 SUBSCRIBE

Get your issues at a discount.

28 HOTSHOTS

Your best astro images revealed.

47 THE SKY IN NOVEMBER

Your 15-page guide to the night sky featuring the top sights, an all-sky chart, a deep-sky tour and more...



78 SKILLS

78 The Guide

Understanding spectroscopy.

81 How to

Make a pipe spectrometer.

84 Image Processing

Calibrating with flat frames.

87 Scope Doctor

89 REVIEWS

Tried and Tested

90 Orion Optics VX8 f/4.5 Newtonian reflector.

First Light

94 Vixen AP-SM mount.

98 Baader Morpheus eyepiece series.

102 Books

104 Gear

106 WHAT I REALLY WANT TO KNOW IS...

Why do galaxies stop making stars?

FEATURES

C = on the cover

32 UNCOVERING THE KUIPER BELT

C The story of the outer Solar System region being explored by New Horizons.

38 IMAGING UNDER CITY SKIES

C An urban astronomer tells us how he beats London's light pollution to take deep-sky shots.

44 THE UNIVERSE IN 3D

Inside Britain's first 3D planetarium.

62 ROSETTA: THE JOURNEY SO FAR

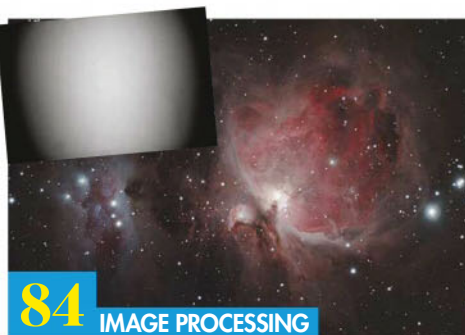
C We reflect on a year of revelations from the Rosetta spacecraft around comet 67P.

69 EXOPLANETS IMAGINED

C NASA illustrators tell us how they create artwork of worlds that no-one has laid eyes on.

74 15 YEARS ON THE ISS

NASA astronaut Scott Parazynski reveals what life is like at 400km above Earth.



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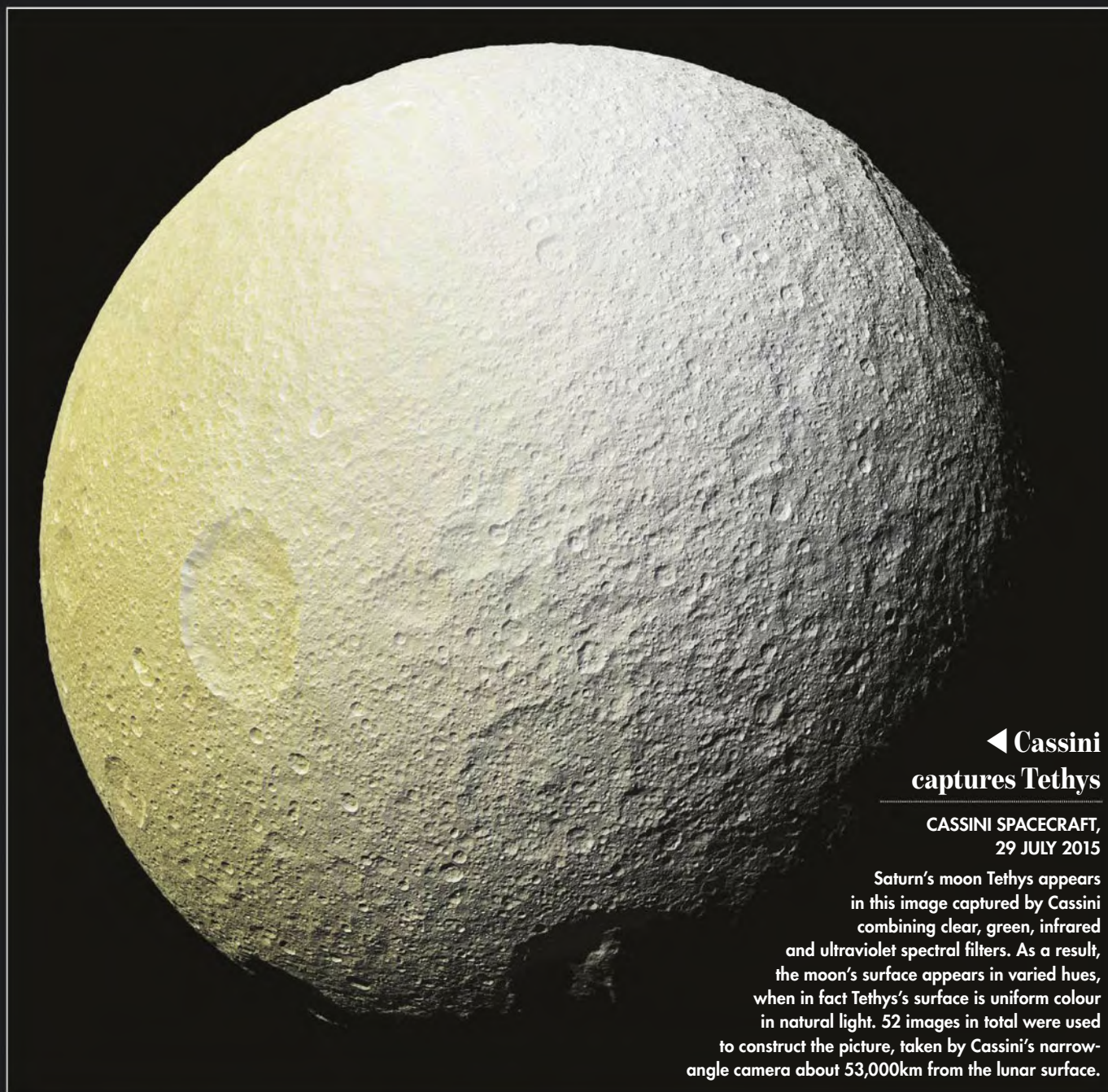
Monkey business

The Monkey Head Nebula appears as a multi-coloured swarm of stars, space dust and cosmic clouds in infrared wavelengths

SPITZER SPACE TELESCOPE, 20 AUGUST 2015

Often, the descriptive nicknames given to nebulae match their appearances exactly, but this is not the case in this image of the Monkey Head Nebula taken by NASA's Spitzer Space Telescope. The reason is because of the infrared properties of the image, which hide the 'monkey face' seen more clearly in wide-field depictions of the nebula in the visible part of the spectrum. However, this view does show us multiple cradles of infant stars, seen here as red spots of light. Dust surrounding the stars glows brightly in the infrared wavelengths, but will eventually be carved away as the stars grow.

The nebula is located in the northern parts of Orion, 6,400 lightyears away. It is an energetic stellar nursery full of all the basic ingredients required for star formation. However, a large proportion of this star-making material gets blown away by hot young stars that generate high-velocity winds. Nevertheless, NGC 2174 remains a highly radioactive, violent and productive nebula.



◀ Cassini captures Tethys

CASSINI SPACECRAFT,
29 JULY 2015

Saturn's moon Tethys appears in this image captured by Cassini combining clear, green, infrared and ultraviolet spectral filters. As a result, the moon's surface appears in varied hues, when in fact Tethys's surface is uniform colour in natural light. 52 images in total were used to construct the picture, taken by Cassini's narrow-angle camera about 53,000km from the lunar surface.

Antarctica's aurora australis ▶

BETH HEALEY, 18 AUGUST 2015

Beth Healey is a British doctor working at the Concordia station in Antarctica for ESA. It was from there that she took this amazing image of the aurora australis, highlighting not only the beauty of aurorae when seen under clear skies, but also the barren and isolated landscape in which the 13-strong crew spend the winter months at the station. Cold, dark and with less oxygen than warmer climes, the conditions are similar to those of distant planets, which is why ESA sponsors a medical doctor to work on site and conduct research for future space missions.





◀ An explosive pairing

HUBBLE SPACE TELESCOPE, 21 AUGUST 2015

This Hubble image has captured the cosmic pairing of star WR 124 and the nebula M1-67 surrounding it. These objects are found in Sagittarius 15,000 lightyears away. WR 124 is a Wolf-Rayet star, a massive body that has lost its outer hydrogen layer, creating strong emission lines as winds of material are blown outward. The star shines brightly at the centre of the image, while hot gas is propelled outward at speeds over 150,000km per hour.

▼ Cosmic cluster laboratory

LA SILLA OBSERVATORY, 19 AUGUST 2015

The enormity of open star clusters is evident in ESO's image of IC 4651, taken at the La Silla Observatory in Chile. The fact that most stars form within clusters makes them perfect cosmic laboratories for astronomers to study the birth, life and death of stars. Over a thousand open star clusters are known to exist in the Milky Way alone and their study enables astronomers to learn more about the evolution of the Galaxy.





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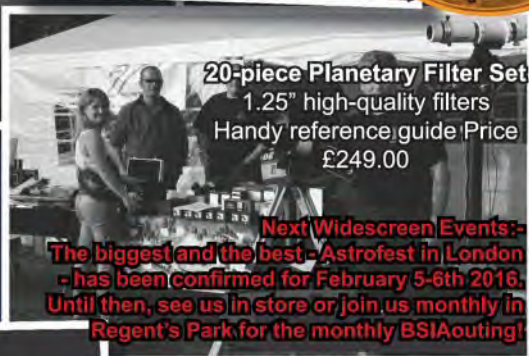
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Lunar photo by Widescreen customer Richard Maun; Main BSIA image by Tom Kerss. Sadr nebula by Geoffrey Lenox-Smith



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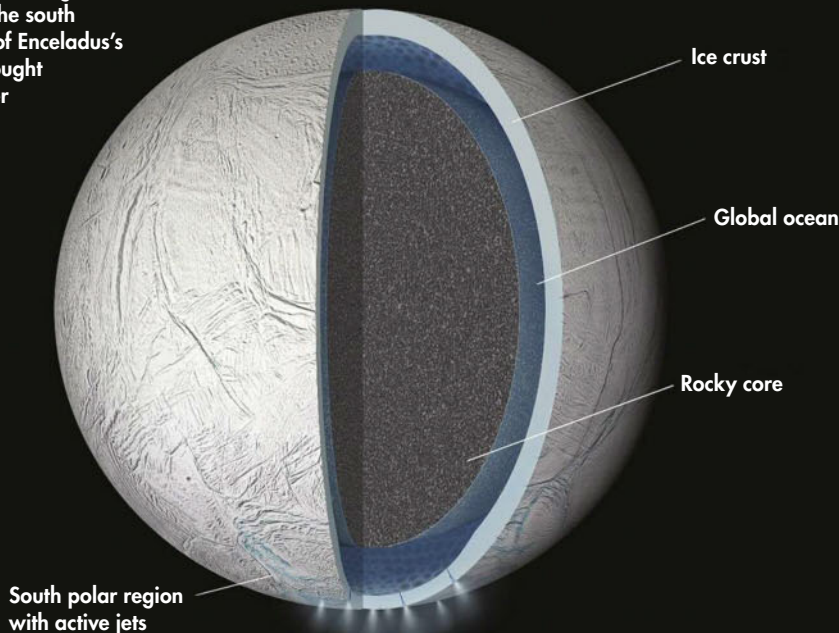
14 CHRIS LINTOTT
16 LEWIS DARTNELL

EDGE

The latest astronomy and space news written by **Elizabeth Pearson**

Our experts examine the hottest new astronomy research papers

Once suspected of being localised under the south pole, the extent of Enceladus's ocean is now thought to be much larger



Cassini finds global ocean on ENCELADUS

The liquid layer sloshes the moon's crust as it is gently pulled by Saturn

THE OCEAN UNDER the crust of Saturn's moon Enceladus encompasses the entire world, according to the latest data from NASA's Cassini mission. This is the first solid evidence that the ocean is global, though we have been aware of the presence of a subsurface sea of some form for a decade.

The extent of the ocean was discovered by Enceladus's slight wobble, which was measured from over seven years of images taken by Cassini.

"If the surface and core were rigidly connected, the core would provide so much dead weight the wobble would be far smaller than we observe it to be," says Matthew Tiscareno, a Cassini participating scientist at the SETI Institute. "This proves that there must be a global layer of liquid separating the surface from the core."

In 2005 the Cassini probe discovered icy plumes gusting from the planet's surface, suggesting the presence of liquid beneath the crust. Ever since there has been much debate about what this ocean was really like.

Previously it was thought that the ocean was constrained to an area under Enceladus's southern pole. However, Cassini measured the moon's gravitational map over several passes and found that a global ocean layer was more likely and the new analysis seems to confirm this theory. "This was a hard problem that required years of observations, and calculations involving a diverse collection of disciplines, but we are confident we finally got it right," says Peter Thomas, a Cassini imaging team member at Cornell University.

► See Comment, right



COMMENT by Chris Lintott

The news that Enceladus's ocean is global delivers a good kick to theorists studying this strange, small world, who will need to explain why such an ocean hasn't frozen yet. Enceladus, remember, is about the size of England – too small, we presume, to have an internal heat source capable of keeping a substantial body of water in a liquid state.

One possibility is that Saturn's tidal forces are generating more heat than expected, pushing and pulling the interior of the moon about as it orbits. Another is that interactions with other satellites occasionally provide a boost in energy.

Whatever the answer turns out to be, the point is that discovery brings more questions as well as answers. As Cassini sweeps through the plume in October, not even 50km above the surface – its closest approach to the active region – we may get more clues. Enceladus hasn't finished surprising us yet.

CHRIS LINTOTT co-presents *The Sky at Night*

NEWS IN BRIEF

HOT ROCKY WORLDS COULD BE HABITABLE

Rocky exoplanets in tight orbits around their parent stars could be habitable. Most worlds that fit this description are tidally locked, meaning the same side always faces the star, but simulations have shown this doesn't always mean that one side is scorching and the other freezing – wind and weather patterns may mix the air and distribute heat. “We examined exoplanets with different rotation periods and sizes,” says Ludmila Carone from the University of Leuven, “and we discovered that these rocky planets have three possible climates, two of which are potentially habitable.”



UK TO LEAD E-ELT INSTRUMENT

UK researchers will lead the creation of HARMONI, one of the first instruments on the European Extremely Large Telescope (E-ELT). HARMONI will observe spectroscopically and visually at the same time. “It will revolutionise observational astronomy through the 2020s and beyond,” says Prof Niranjana Thatte from the University of Oxford.



Liquid water found On Mars

The discovery could have implications for future missions to the Red Planet

LIQUID WATER HAS been confirmed on the surface of Mars. New evidence from NASA's Mars Reconnaissance Orbiter (MRO) has found that water is responsible for dark streaks seen on the Martian surface.

Shaded patches, called recurring slope lineae, were spotted growing on the Red Planet several years ago. These mysterious streaks appear in various places across the Martian surface during the warm season, when temperatures reach a relatively balmy -23°C . They seemingly flowing down slopes until the temperature drops again, when the lines fade and then disappear.

It's long been thought that the lineae are caused by highly briny water in Mars's surface melting and refreezing, but there has been no direct evidence until now. This evidence comes in the form of observations taken by MRO's CRISM instrument, which revealed not only the spectroscopic signatures of salts that have been hydrated by water at multiple locations when the streaks are present, but also an absence of the signatures when the streaks disappear.

“The detection of hydrated salts on these slopes means that water plays a vital role in the formation of these streaks,” says Lujendra Ojha of the Georgia Institute of Technology. “When most people talk about water on Mars, they're usually talking about ancient water or frozen water. Now we know there's more to the story.”

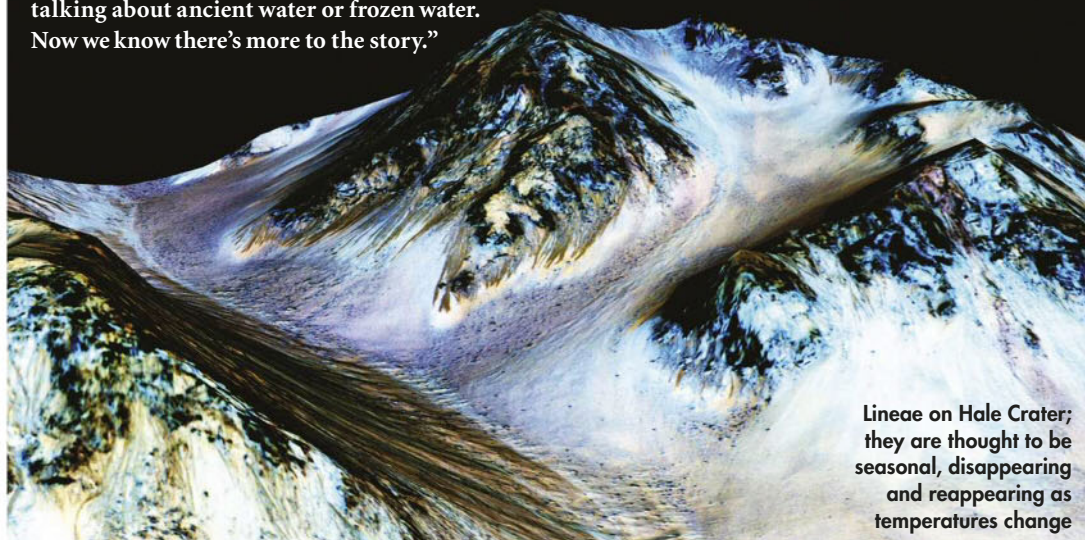


▲ Recurring slope lineae on Garni Crater – the streaks can grow up to several hundred metres long

Though the water is probably too salty for life to exist within it, the finding has great implications for the possibility of current life existing on the planet. However planetary protection regulations mean that no mission can risk contacting potential Mars ecosystems without being properly sterilised.

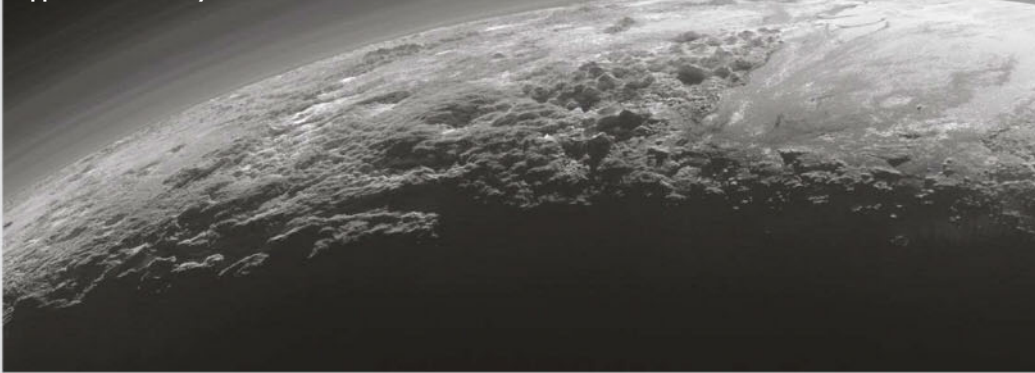
“Our quest on Mars has been to ‘follow the water’ in our search for life in the Universe, and now we have convincing science that validates what we've long suspected,” says John Grunsfeld, associate administrator of NASA's Science Mission Directorate in Washington.

“This is a significant development, as it appears to confirm that water – albeit briny – is flowing today on the surface of Mars.”
<http://mars.nasa.gov>



Lineae on Hale Crater; they are thought to be seasonal, disappearing and reappearing as temperatures change

New Horizons captured this sunset view just 15 minutes after its closest approach on 14 July



New Horizons reveals more of Pluto

The latest shots show icy mountains and hazy plains

NEW HORIZONS HAS started sending full resolution images of Pluto back to Earth. The above image depicts the view the craft took as it looked back at Pluto, allowing it to study the planet's atmosphere as sunlight travels through it. Also striking in the image are the icy mountains that stand 3.5km tall, far higher than anything that was expected.

"This image really makes you feel you are there, at Pluto, surveying the landscape for yourself,"

says New Horizons principal investigator Alan Stern, of the Southwest Research Institute. "But this image is also a scientific bonanza, revealing new details about Pluto's atmosphere, mountains, glaciers and plains."

It takes 42 minutes to download each image, and it will be 16 months before the full catalogue reaches Earth.

<http://pluto.jhuapl.edu>

► Learn more about the Kuiper Belt on page 32

NEWS IN BRIEF

NITROGEN COULD AID HUNT FOR LIFE

A new method to spot atmospheric nitrogen in exoplanets could help us to work out which worlds have enough air pressure to keep surface water stable. The difficult-to-spot gas could be traced by searching for the spectroscopic signature created by colliding molecules.

"If there's enough nitrogen to detect at all, you've confirmed that the surface pressure is sufficient for liquid water," says Edward Schwietzman from University of Washington.



STELLAR TWINS HELP MEASURE THE MILKY WAY

By looking at similar stars, researchers can measure distances in the outer limits of our Galaxy, which are hard to calculate with traditional techniques. The method requires finding stars with similar spectra and then comparing their brightnesses. "The further away a star is, the fainter it appears in the sky," says Jofre Pfiel from The University of Cambridge. "If two stars have identical spectra, we can use the difference in brightness to calculate the distance."



Mogensen completed a series of trials with a rover on Earth while he was on the ISS



ORBITAL ROVER TEST A HUGE SUCCESS

ESA ASTRONAUT ANDREAS Mogensen has successfully driven a robotic rover on Earth while in orbit aboard the International Space Station. The Danish astronaut performed several remote control tasks during his stay on the ISS, which included driving rovers around, using them to pick up items and manoeuvring them to perform precision tasks.

The tests simulated the conditions that might be expected for astronauts operating rovers from orbit;

such as dealing with a time delay and momentary drops in the connection between ground and orbit.

"He had never operated the rover before but its controls turned out to be very intuitive," says André Schiele, head of the Telerobotics and Haptics Laboratory at ESA. "Andreas took 45 minutes to reach the task board and then insert the pin on his first attempt, and less than 10 minutes on his follow-up attempt."

<http://esa-telerobotics.net>

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EDGE

Cold stars in hot clusters

Cool red supergiants like may fill globular clusters with the gas needed to form new stars



Globular clusters are fascinating places. These cities of hundreds of thousands of stars are mini-galaxies in their own right, and they form fascinating laboratories for trying to unravel the intricacies of stellar behaviour.

Take the mix of heavy elements found in the stars that populate such a cluster. They did not form in the Big Bang, which produced almost nothing but hydrogen and helium, but in previous generations of stars. Sometimes this material is spread when a star explodes, but a surprisingly effective route is via the winds of hot stars. Massive stars are expected both to be unstable and to lose plenty of material. But there's a catch with this explanation – the material which escapes is hot, and liable to escape the globular cluster altogether.

The only solution is to find ways of cooling the material in the wind so it stays bound to the cluster, ready to form new stars, but a new paper provides plenty of evidence to support a different interpretation. Maybe the source of heavy element-rich material is not in hot stars at all, but rather from cooler, red supergiants such as Betelgeuse.

▲ Globular cluster Westerlund 1 is home to both hot and cold massive stars – it's the one place we know of where this model might work



CHRIS LINTOTT is an astrophysicist and co-presenter of *The Sky at Night* on BBC TV. He is also the director of the Zooniverse project.

This suggestion makes a certain amount of pragmatic sense. Stars with a mass less than 30 times that of the Sun will release more material during the red supergiant phase than at any other stage, and the material that is lost will be cool, making it easier to keep in the cluster. To test the model, though, we need to find a cluster that has both hot and cold massive stars at once, and to see how they behave.

Precisely one such cluster is known. Westerlund 1 is the most massive young cluster in the Milky Way, and as it is only four million years old even the most massive hot stars are still present. Even better, the cluster is close enough that individual stars can be easily studied, and this work brings together simulations and observations of one star in particular, designated W26.

W26 is a bright red supergiant, surrounded by a bright nebula. This is exciting, because the presence of excited gas surrounding the star suggests that it's not just flowing out into space, but rather being constrained by its surroundings, most likely by interaction with the bright light produced by the other cluster stars.

“Maybe the source of heavy-element rich material is not in hot stars at all”

All of this is highly encouraging, but there are mysteries remaining. The structure around W26 is strangely not symmetric, and so the researchers look around the neighbourhood for likely explanations. Less than a lightyear away lies W9, a truly spectacular star – the brightest radio emitter in the cluster and the source of a wind that expels a Sun's worth of mass every 2,500 years.

This wind, the authors suggest, might collide with that from W26, resulting in both the observed asymmetry but also shocking and then slowing down the wind from both stars. If this is the case, then studying stars in isolation will not solve the mysteries of a decent globular – we must, satisfyingly, think of the cluster as a whole.

CHRIS LINTOTT was reading... *Cold gas in hot star clusters: the wind from the red supergiant W26 in Westerlund 1* by Jonathan Mackey, Norberto Castro, Luca Fossati and Norbert Langer.

Read it online at <http://arxiv.org/abs/1508.07003>

NEWS IN BRIEF

VOLUNTEER BLACK HOLE HUNTERS ARE AS GOOD AS THE EXPERTS

Amateurs are as good as the professionals when it comes to detecting massive black holes and matching them to their host galaxies. Radio Galaxy Zoo, a citizen science project, compared the findings of a team of volunteers after a short training session to those of a panel of experts and found they were just as good.

"In the upcoming all-sky radio surveys, we are expecting 70 million sources – 10 per cent of which will not be classifiable by computer," says Dr Ivy Wong of the International Centre for Radio Astronomy. "These 10 per cent will have weird and complex structures that need a human brain to interpret and understand, rather than a computer program."



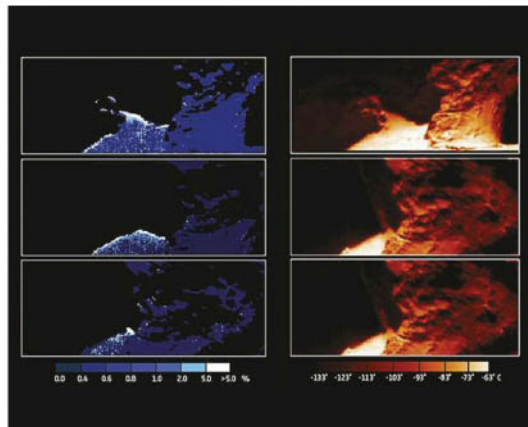
EXOMARS DATE SET FOR 2016

The launch window for ESA's Martian orbiter has been delayed to 14-25 March 2016 due to a problem with two of the sensors in the propulsion system. The probe will still reach Mars in October next year.



Comets have water-ice cycle

Rosetta data suggests that comets refresh their surface ices



▲ Rosetta detected a correlation between the comet's water-ice (left) and fluctuations in temperature (right)

COMETS REFRESH THEIR icy surfaces during the night, new Rosetta data has shown. Sunlight sublimates surface water-ice, turning it into a gas that escapes, but when the comet is in shade warm subsurface layers continue to sublimate. When the water vapour reaches the surface it freezes, covering the comet in a fresh layer of ice.

"We saw the tell-tale signature of water-ice in the spectra of the study region but only when certain portions were cast in shadow," says study author Maria Cristina de Sanctis. "Conversely, when the Sun was shining on these regions, the ice was gone. This indicates a cyclical behaviour of water-ice during each comet rotation."

www.jpl.nasa.gov

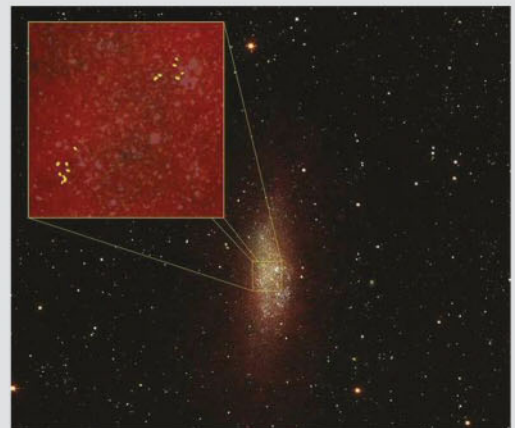
► For a full update on Rosetta turn to page 62.

HOW DWARF GALAXIES FORM STARS

THE WAY THAT stars form in dwarf galaxies may have finally been explained. It's been uncertain how these small bodies form stars, as they appeared to lack one of the vital ingredients, carbon monoxide. ALMA has now detected tiny clouds of the gas in dwarf galaxy Wolf-Lundmark-Merlott (WLM), so condensed into small regions that previous surveys hadn't seen them.

"By discovering that the carbon monoxide is confined to highly concentrated regions within a vast expanse of transitional gas, we could finally understand the mechanisms that led to the impressive stellar neighbourhoods we see in the galaxy today," says Bruce Elmegreen from the IBM Thomas J Watson Research Center.

<http://public.nrao.edu/telescopes/alma>



Carbon monoxide only exists in WLM in small pockets (yellow), but this is enough to allow star formation

Looking back The Sky at Night

November 1960

On 11 November 1960, *The Sky at Night* focused on an often unseen side of the Space Race, examining the work of the Soviet space agency. In the late 1950s, the USSR looked as if it would dominate space, having beaten the US in launching the first probe in the form of Sputnik and putting Laika the dog into Earth orbit. The early 60s would see even more successes as the Soviets launched the first man and woman into space (Yuri Gagarin in

1961 and Valentina Tereshkova in 1963), and the first probes to another planet in the form of the Venera spacecraft.

But as the 60s wore on, the Soviet space programme began to flag and, after being beaten to the Moon by NASA's Apollo programme, its ambitions took a different direction. Focusing on low-Earth orbit, the Russians built Salyut-1, the first in a line of space stations that has culminated in the ISS.



Launched in October 1957, Sputnik was humankind's first artificial satellite

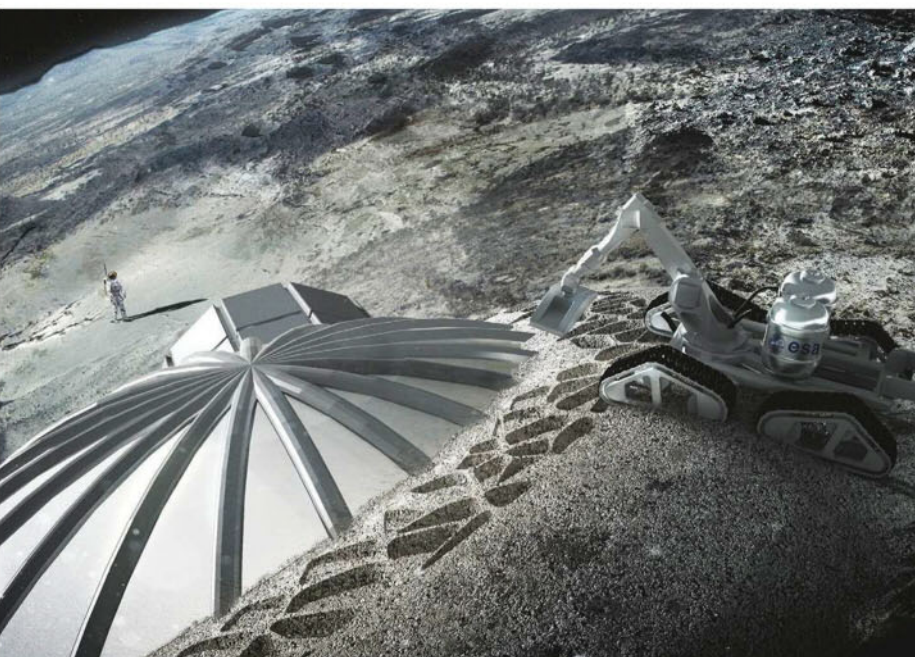
CUTTING

Our experts examine the hottest new research

EDGE

How to build a moonbase

Future lunar explorers may be able to build permanent habitats from local materials



One of the biggest challenges of developing a long-term human base on the surface of the Moon is what we could use as a construction material.

Anything launched all the way out of Earth's gravity and flung to the Moon (what space engineers call 'upmass') is incredibly expensive. This means that, as far as possible, we will need to make use of materials and substances we can find on the Moon already. This is called in-situ resource utilisation, and includes efforts such as searching for areas that may hold water-ice on the Moon that could be exploited in a lunar habitat life support system.

Carlos Montes of the Louisiana Tech University Institute for Micromanufacturing and colleagues believe they have the answer. They have been testing a geopolymer binder construction material they call Lunamer, which is very similar to concrete. Concrete is composed of lumpy filler material, or aggregate, all bound together with Portland cement that sets hard as rock through a chemical reaction.

Montes says that the meteorite-pulverised regolith that can be scraped right off the lunar surface has the right balance of very fine particles

▲ The regolith that sits atop the lunar crust could be the key ingredient in future lunar habitats



LEWIS DARTNELL is an astrobiologist at the University of Leicester and the author of *The Knowledge: How to Rebuild our World from Scratch* (www.the-knowledge.org)

that participate in the chemical binding process and larger lumps that serve well as aggregate. And luckily the regolith also has roughly the same chemical composition of aluminium and silicon oxides as fly ash, which is used in terrestrial cement.

Assuming lunar ice can offer a source of water, the only part for the Lunamer construction material that would need to be launched from the Earth is an 'activator' fluid, containing concentrated sodium hydroxide. This additive triggers the setting process, and a little goes a very long way – the geopolymer concrete is made with 50 times more regolith than this binding agent. This is hugely significant, as it currently costs an estimated \$20,000 for every kilogram of payload launched into low-Earth orbit, and a great deal more on top of that to transport cargo to the Moon's surface.

Not only have Montes and his team shown that this Lunamer concrete is easily strong enough for building moonbases and offers good thermal insulation, but it also serves well as radiation

“Not only is this concrete good for building, it serves well as a radiation shielding material”

shielding material. Astronaut exposure to cosmic radiation from solar flares or background galactic cosmic rays is a huge concern for long-duration space missions. Montes has calculated that a lunar habitat built with 1m-thick Lunamer walls will reduce the annual radiation exposure to what has been deemed acceptable on Earth.

The team also point out that Lunamer concrete would not only be useful for constructing and shielding bases on the lunar surface, but possibly also as protective cladding fixed around spacecraft then launched onwards from the Moon towards the other planets and beyond. As Montes puts it, “With this technology, it could be possible in the future for stripped-down spacecraft to be delivered from Earth to the Moon, equipped with Lunamer panels, and re-launched from the lunar surface to reach a final destination in deep space.”

LEWIS DARTNELL was reading... *Evaluation of lunar regolith geopolymer binder as a radioactive shielding material for space exploration applications* by Carlos Montes et al

Read it online at <http://dx.doi.org/10.1016/j.asr.2015.05.044>

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What's on

Our pick of the best events from around the UK

An Hour on the Moon

Wills Memorial Building, University of Bristol, 25 November, 6pm



PICK
OF THE
MONTH

▲ Jon Culshaw with Colin Pillinger while filming for *The Sky at Night* in 2013

Comedian, astronomer and *BBC Sky at Night* Magazine columnist Jon Culshaw hosts an evening celebrating British scientist Colin Pillinger, best known for his involvement with the Mars lander Beagle 2.

Speakers at the first Colin Pillinger Memorial Talk include Dr Marek Kukula, public astronomer at the Royal Observatory Greenwich, ESA's Dr James Carpenter and author Peter Cadogan, who worked on Apollo samples in

Bristol. Dr Matt Taylor will lead a talk on the Rosetta mission, a project in which Pillinger played a key role.

Colin's widow Judith says: "It is very fitting that we are able to hold the event in the city he loved. Colin was always ready to share his enjoyment of science with the public and we hope this annual lecture will carry on his legacy."

The event is free and open to the public, but tickets must be booked in advance. www.bristol.ac.uk

BEHIND THE SCENES THE SKY AT NIGHT IN NOVEMBER

BBC Four, 8 November, 10pm (first repeat **BBC Four, 12 November, 7.30pm**)*



Rocky planets are common, but potential Earth analogues are few and far between

A SECOND EARTH?

As we close in on the discovery of the 2,000th exoplanet, *The Sky at Night* investigates our continuing search for planets orbiting other stars. Looking into the techniques that are revealing so much about these alien worlds, the programme asks: are we really any closer to finding another world like our own – a second Earth?

*Check www.bbc.co.uk/skyatnight for subsequent repeat times

Colliding Galaxies

Geological Society Lecture Theatre, London, 10 November, 1pm; Royal Astronomical Society Lecture Theatre, London, 10 November, 6pm



What happens when galaxies collide? Dr Megan Argo of the Jodrell Bank Centre for Astrophysics reveals what galaxies are made of and how they are formed. The lecture will offer a bird's-eye view of the Milky Way, a look at what happens when gravity becomes irresistible and will end with a view of our own distant future. Attendance is free but on a first-come, first-served basis.

www.ras.org.uk

Starting from Scratch

Juniper Hall, Dorking, 7 November, 9.30am



The Society for Popular Astronomy hosts a day of talks for those new to observing: covering the naked eye, binoculars and telescopes, the Sun, the Moon, planets and the deep sky. Speakers include authors and broadcasters Robin Scagell and Jerry Stone, and astronomers Martin Lewis and Neil Phillipson. Dr Jen Gupta of the University of Southampton also gives a talk on the formation of the Solar System and Universe. Tickets cost £10.

www.popastro.com/courses

Astronomy Day

National Museum of Flight, East Lothian, 14 November, 10am



This Astronomical Society of Edinburgh event includes planetarium shows, astrophotography, solar observing and a stargazing session from 6pm-9pm. There are also talks on spaceflight as well as 'comet making' and children's craft activities. Tickets are £10 for adults, £8 concessions, £5 for kids, £26 for a family of two adults and two children. Free for museum members.

www.astronomyedinburgh.org

MORE LISTINGS ONLINE

Visit our website at www.skyatnightmagazine.com/whats-on for the full list of this month's events from around the country.

To ensure that your talks, observing evenings and star parties are included, please submit your event by filling in the submission form at the bottom of the page.



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BBC Sky at Night Magazine

Explorer-130M
Model illustrated

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BBC Sky at Night Magazine



EXPLORER-130P 130mm (5.1") F/650 PARABOLIC NEWTONIAN REFLECTOR TELESCOPE

- Magnifications (with optics supplied): x26 & x65
- Highest Practical Power (Potential): x260
- Diameter of Primary Mirror: 130mm
- Telescope Focal Length: 650mm (f/5)
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Astronomy Now Magazine

Sir Patrick Moore Endorses Sky-Watcher Telescopes



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A PASSION FOR SPACE



with **Maggie Aderin-Pocock**

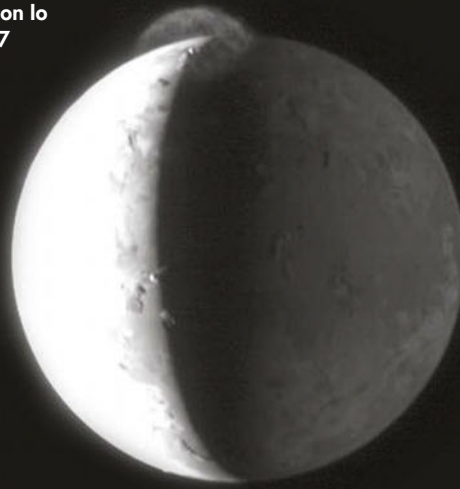
The Sky at Night presenter wonders how Earth's tallest volcano measures up to others in the Solar System

I have always been in awe of volcanoes and my first ever encounter with an active one did not disappoint. I took a post-sunset trip to Mauna Kea in Hawaii, the tallest volcano on Earth. It seemed amazing (and a little scary) that I could stand with my feet just a few inches from the lava flow. So close, in fact, that in the dark of night I could see the glow of the lava and feel a flush in my cheeks caused but the heat radiating from the flow.

Surprisingly, a very simple way to look at what causes a volcanic eruption is to analyse the classic diet cola and mints experiment. The cola represents the magma (liquid rock) and just like the magma in a real volcano it has large volumes of gas dissolved into it. The mints represent crystals that have cooled and condensed out of the magma.

Both the mints and the crystals act as activation sites, where bubbles form on rough surfaces. As the bubbles come out of solution, a cascade effect ensues and more of the gas is drawn out too. The bubbles adhere to the rough surface of the mints (or crystals), reducing their overall density and causing them to rise through the solution. The discharged gas increases the volume contained within the bottle (or volcano), increasing the pressure in the

New Horizons spotted a 330km plume on Io in February 2007



system until that pressure is released by the gas (or magma) shooting out of the top of the bottle (or volcano).

Ice and fire beyond Earth

Earth's volcanoes are impressive, but we are also finding more and more of them out in the Solar System. Looking out at our nearest neighbours, Mars takes the prize for the largest. The now extinct Olympus Mons stands 25km tall. Mauna Kea rises only 4.2km above sea level; even measured from Earth's crust below the water line, it's just 9km.

Radar images show that Venus is peppered with volcanoes, most relatively flat compared to the ones seen on Earth and Mars. Until recently it was thought that the volcanoes on Venus were inactive, but measurements

taken by ESA's Venus Express have revealed significant changes in the levels of sulphur dioxide in the atmosphere. Here on Earth the only naturally occurring source of sulphur dioxide is volcanoes. This, coupled with the transitory hotspots that appear on the surface, seems to give strong evidence that there are in fact active volcanoes on Venus.

Moving farther out we have found still more eruptions, but these stem from cryovolcanoes.

Instead of molten rock, these volcanoes erupt with cold or frozen gases such as water, ammonia or methane.

One of the pictures taken by New Horizons as it made its way to Pluto shows a huge jet of material thrown into space from the Galilean moon Io, Jupiter's fourth largest moon. New Horizons later took images of volcanoes on both Pluto and Charon. The mechanism by which some of these smaller bodies are able to generate the heat required for these outbursts is still a mystery. But we are finding more and more incidents of volcanism in the Solar System and these will hopefully provide the evidence we need for robust theories in the future. **S**

Maggie Aderin-Pocock is a space scientist and co-presenter of *The Sky at Night*

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JON CULSHAW'S EXOPLANET EXCURSIONS

Jon scouts out Earth's 'bigger, older cousin', the remarkably similar Kepler 452b

Kepler 452b has been described as the most 'Earth-like' planet ever found. How fascinating would it be to take a trip and see precisely how similar it is to our pale blue dot. I've set coordinates set for its parent star Kepler 452, which sits 1,400 lightyears away in Cygnus. Kepler 452 is quite like our Sun though 1.5 billion years older, 20 per cent brighter and four per cent more massive. It shines the reassuring solar yellow of a star still in the surety of the main sequence.

Steering into the system's habitable zone, the magnificent 'super-Earth' Kepler 452b appears with imposing majesty. It's strangely disconcerting. Similarities to our own Earth – the swirling white and blue, the ochre, green and khaki – bring a feeling not of confidence in familiarity but of caution and not wishing to fall into a false sense of security. There could be an infinite number of ways that this planet is different to our own. I steer the Perihelion with great trepidation as if driving into a part of town with a volatile reputation.

Upon landing, the sense of confusion grows. At first view, this world appears

so very much like ours it's quite bizarre to take in. There's an expectation for exoplanets to be profoundly different, odd and alien. This localised area is something like Earth's Oligocene epoch around 30 million years ago.

After a time, once you've got your bearings, the fascinating unique features of this world start to become apparent – similar to becoming dark adapted.

There's evidence of volcanic and geologic activity leaving results quite unlike those we see on Earth.

The larger scale of this world and much greater gravity has fashioned what I can only describe as a furiously whisked and churned geology. It looks to have been busier, faster and more intensive than the processes we studied in Mr Malley's geology lessons at school.

I fly 300km to be greeted with a totally alien vista – a staggering feature befitting the super-Earth status of the planet. Ahead of me is an immense canyon, rolling forward as far the eye can see, on the scale of the Valles Marineris on Mars. But this resembles the Valles Marineris of a terraformed Mars in the

far future. There are pockets of sandy-coloured liquid lakes with dark green foliage resembling giant, leathery rhubarb leaves. They're probably photosynthesising perfectly happily.

An Earth-like world with its terrain and gold starlight. A

Mars-like world with geological landscapes on colossal scales. It's perhaps becoming a Venus-like world too? This planet receives 10 per cent more energy from its star than Earth does from the Sun, so maybe a runaway greenhouse effect is underway? The patchwork of lakes does look like it has been evaporating into the atmosphere.

Such a diverse world inspires more questions than answers. The gravity here too, on a planet 60 per cent more massive than Earth, is utterly punishing. I feel I'm being pushed back inside a whirling, fairground centrifuge ride. Although once adapted to it I'll be confident enough to duke it out with a heavyweight boxer all the way back on Earth.

Jon Culshaw is a comedian, impressionist and guest on *The Sky at Night*





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This month's top prize: four Philip's books

The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Robin Scagell and David Frydman's *Stargazing with Binoculars* and Heather Couper and Nigel Henbest's *Stargazing 2016*

PHILIP'S



SOCIAL MEDIA

WHAT YOU'VE BEEN SAYING ON TWITTER AND FACEBOOK

Have your say at twitter.com/skyatnightmag and facebook.com/skyatnightmagazine

@skyatnightmag asked: How did you get on with the lunar eclipse?

David Gosnell Nowhere near as pretty as the 2007 one, which looked like a perfect red billiard ball.

@MoonSpaceBuzz Stunning and the starlit sky was so bright. :)

Alison Cable Did you see the ISS zoom past through the telescope? Made me 'Wow' out loud!

@FamilyoFlowers It was amazing! Before the fog crawled in...

Lesley Evans We found that the colours were much deeper viewed by the naked eye than through a telescope or binoculars.

Interactive

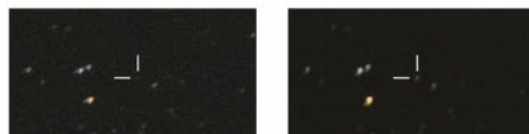
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MESSAGE OF THE MONTH

I found an uncatalogued variable star

I have only recently taken up observing and astrophotography. Last year I bought a secondhand Sky-Watcher Explorer 130P-DS telescope and an EQ-5 mount. My first deep-sky project back in September 2014 was M27 and I revisited the target in August, this time with autoguiding. When I was done processing, it was only natural to blink the two images and to compare quality, but also to see if any interesting changes could be spotted. To my big surprise, I spotted a faint star that apparently changed magnitude. In 2014 it was faint, in 2015 much brighter. I tried to find out what variable star it might be, but I couldn't find any at the coordinates. With a lot of help I found out that the star is identified as IRAS 19597+2258 and that it was not yet catalogued as a variable. I wrote to American Association of Variable Star Observers with details



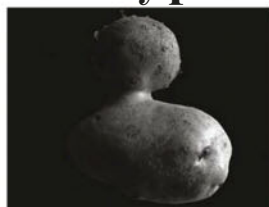
▲ Rudi's shots clearly show that IRAS 19597+2258 was brighter in 2015 (right) than 2014 (left)

of my observations, and they confirmed that it was a new discovery, so now I have made a small contribution to science! To me this proves that every amateur astronomer with only basic equipment (and a little luck) can contribute to science and astronomy from their back gardens.

Rudi Bjørn Rasmussen, Svendborg, Denmark

Congratulations Rudi! It just goes to show what you can achieve with persistence and a keen eye. – Ed

You say potato...



Shortly after Comet 67P/Churyumov-Gerasimenko passed perihelion I managed to image a new comet that looked very similar. I have

provisionally called it Comet 2015/Solanum-Tuberosum. I thought you might like a copy of the discovery image, taken with a Canon Powershot SX50 HS and processed in Photoshop Elements.

Stephen Smith, Nottingham

This is why it pays to keep your eyes peeled! Did your spud fuse together like 67P, I wonder? – Ed

An amazing alignment

On 9 June 2015 I found that something very rare was going to happen: the ISS would pass in front of Jupiter, and it would be visible just 30km away from my home. I decided to try and capture it on camera. Because the transit line of this ISS pass was only 50m wide, I had to be very precise in finding a location where the transit could be seen. I also needed a good horizontal view to the west because Jupiter would be only 13° above the horizon at the moment of transit. So I found

a spot with a good western view and arrived three hours before the pass. The sky stayed clear while I set up my 10-inch Newtonian and NEQ6 mount, and then adjusted my planetary camera settings to a really fast shutter speed – the transit would only last about 0.09 seconds! With a few minutes to go I started getting nervous, but when I saw something bright ascending from the horizon I started recording Jupiter and captured the ISS going right through the middle. To see two objects separated by such a great distance aligning perfectly was unforgettable.

Julian Wessel, via email

Well done, Julian. That has to be a first! – Ed



OOPS!

Our October news story 'Lonely supernovae found in space' (*Bulletin*, page 13) states that supernovae were tracked at speeds in excess of 7.2 million kilometres per second. This should be kilometres per hour.

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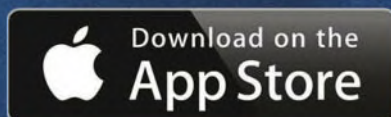
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Hotshots

This month's pick of your very best astrophotos



◀ The Pipe, Lagoon and Trifid Nebulae

CHRISTIAN VAN DEN BERGE,
NAMIBIA, 11 JULY 2015

Christian says: "I love this field of view of the Milky Way. There are so many interesting objects to be seen and I love the contrast between the dark clouds, the yellow background and the bright star clusters. I imaged this during an astro trip to Namibia."

Equipment: Nikon D5100 DSLR camera, Nikkor 80-200mm lens, Fornax 51 mount.

BBC Sky at Night Magazine says: "The dark dust lane that forms the pipe shape, seen vertically in the centre of the image, is amazingly crisp, as are the contrasting pockets of stars and colourful gas. This is a beautifully clear image with an exceptional level of detail."

About Christian: "I started astrophotography in June 2012 when I discovered the amazing results amateurs can achieve nowadays with relatively simple equipment and a normal DSLR. I had been interested in cosmology for years and already had wildlife photography as a hobby. Having a background in daytime photography, I focus a lot on composition and soft processing, particularly colour preservation in stars."



The Orion Nebula ►

WILLIAM DOYEN,
NORMANDY,
FRANCE, 25
DECEMBER 2014

William says: "This was my first attempt at capturing a deep-sky object using the prime focus method. I stacked 10 frames of 30 seconds, and will work on tracking and add a coma corrector to improve star shapes next time."

Equipment used:
Canon EOS 600D
DSLR camera,
Newtonian 200/800,
Meade LXD75 mount.

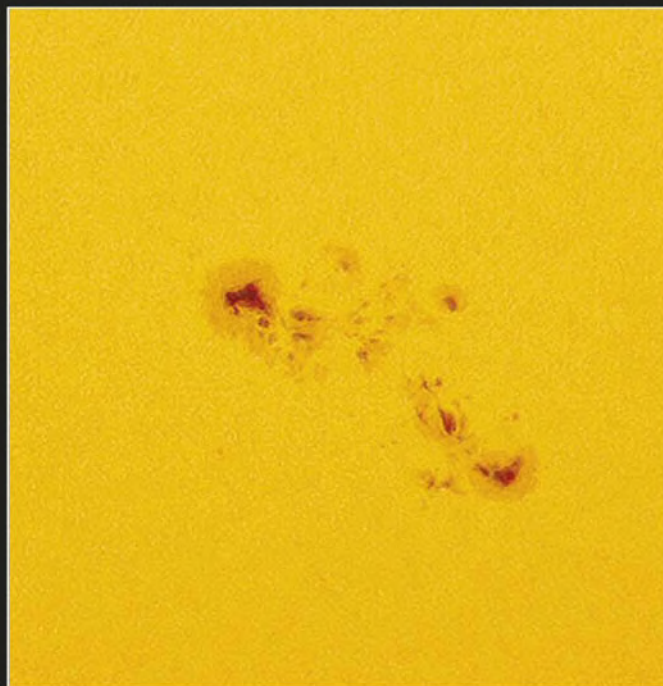


▲ Veil Nebula Eastern Loop

JEAN M DEAN, GUERNSEY, 18 AUGUST 2015

Jean says: "Last year I captured the Western Loop for my father's 86th birthday in September. This year I intended to get the Eastern Loop, but he sadly passed away on 15 August. This is my tribute to him."

Equipment used: Starlight Xpress Trius-SX814 CCD camera, Takahashi FSQ-106ED refractor, Sky-Watcher AZ EQ6-GT mount, Baader RGBL and Ha filters.



◀ Sun Spots

RICHARD WYKES,
OXFORDSHIRE,
22 AUGUST 2015

Richard says:
"I took this picture while away on a break in the Cotswolds with friends. I had people on the campsite viewing the Sun in white light and in hydrogen-alpha."

Equipment used:
Canon EOS 1000D
DSLR camera,
Sky-Watcher
Evostar 80ED Pro
apo refractor,
Lunt solar wedge.



◀ A Perseid over St Cwyfan's Church

KEVIN LEWIS, ISLE OF ANGLESEY,
11 AUGUST 2015

Kevin says: "The 'church in the sea' on Anglesey is perfect for night photography: low light pollution, beautiful foreground interest, peaceful and reasonably accessible. My camera was shooting constantly and it caught early Perseids, tumbling satellites, flares and a stunning display of airglow."

Equipment used: Canon EOS 5D Mark III
DSLR camera, 24-70mm lens.



◀ The Pacman Nebula

MARK GRIFFITH,
SWINDON,
28 JULY 2015

Mark says: "I'm gaining confidence with my new 12-inch telescope and EQ8 mount. This is one of my best images so far. I'm still learning and improving even after three years of deep-sky imaging."

Equipment: Atik 383L+ CCD camera, Teleskop-Service 12-inch Ritchey-Chrétien, Sky-Watcher EQ8 Pro mount, Astronomik SII, Ha, OIII filters, Astro Physics CCDT67 0.67x reducer.

▼ Core of M31 and M32

JASON WISEMAN, DEVON, 17 AUGUST 2015

Jason says: "This image was taken from Holwell Farm in Dartmoor. I think this is my best image to date. Since joining my local astronomy club in Torbay my images have improved greatly."

Equipment: Nikon D90 DSLR camera, Celestron CPC 925 GPS Schmidt-Cassegrain.



▲ Noctilucent aurorae with a Perseid

OLLI REIJONEN, ASIKKALA, FINLAND, 18 AUGUST 2015

Olli says: "I was at our summer cottage at Lake Päijänne and I wanted to photograph the last noctilucent clouds at midnight. There was some light action in the northern horizon so I took the camera and, to my surprise, also managed to capture aurorae and Perseids."

Equipment: Olympus OM-D E-M5 camera, Panasonic Lumix G lens



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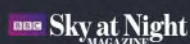
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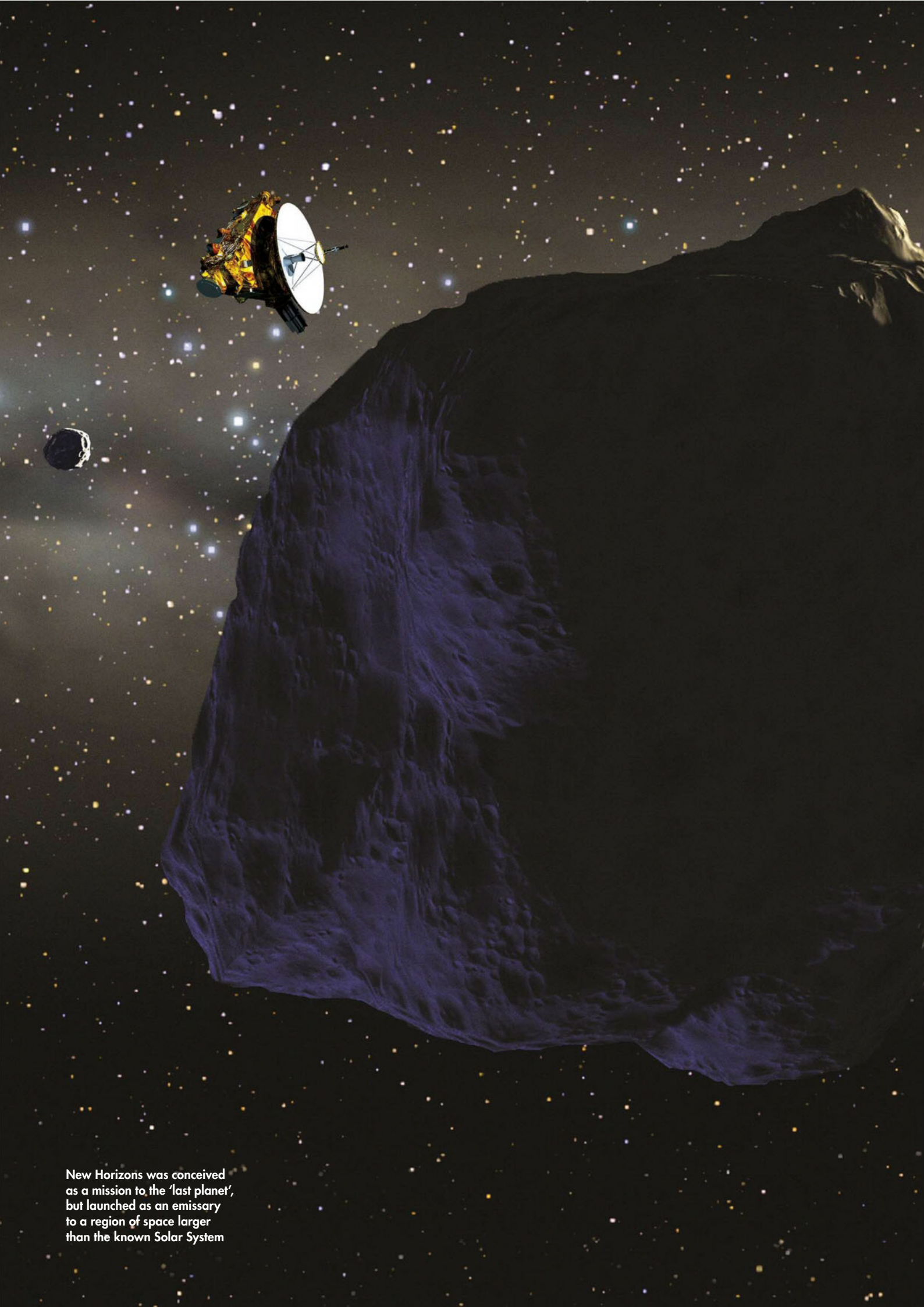


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New Horizons was conceived as a mission to the 'last planet', but launched as an emissary to a region of space larger than the known Solar System



NEW HORIZONS: UNCOVERING THE KUIPER BELT

Dave Jewitt, the scientist who discovered the Kuiper Belt, describes the distant region of space New Horizons is currently exploring

All of the planets out to Saturn were known to the ancients, but it's only in the past few centuries that we have been able to look farther into our own back garden. William Herschel only discovered Uranus by chance in 1781, while Neptune's existence was later predicted on the basis of gravitational perturbations measured in the orbit of Uranus. Building on this, Percival Lowell used still smaller perturbations to predict yet another planet beyond Neptune, subsequently discovered in 1930 by Clyde Tombaugh at Lowell Observatory. This is Pluto.

The 'new planet' caught the attention of the world immediately. Judging by the reaction

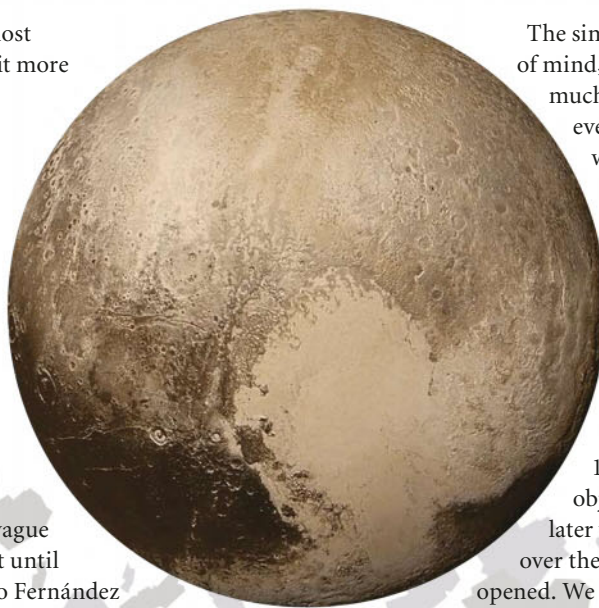
to the New Horizons mission, it still does. Unfortunately, from a scientific perspective, things began to unravel for Pluto soon after its discovery. Unlike the ice giants Uranus and Neptune, each about 16 times Earth's mass, Pluto turned out to be an unimpressive 0.002 Earth masses, or one-sixth of the mass of the Moon.

Tiny Pluto is far too small to perturb an ice giant. Even stranger, the perturbations used by Lowell to predict Pluto turned out to be just errors in the measured position of Uranus, rendering his prediction baseless. All evidence for an unseen massive body in the outer Solar System promptly evaporated leaving only tiny ▶

► Pluto, whose label as the smallest, most eccentric, most inclined 'planet' gave it more importance than it perhaps deserved.

A number of scientists such as Fred Leonard in 1930, Kenneth Edgeworth in 1943, Gerard Kuiper in 1951 and Fred Whipple in 1964, speculated that Pluto might not be alone.

Kuiper went a step too far, though, and actually predicted that the region where we discovered the Kuiper Belt formed full but is now empty because of destabilising perturbations by Pluto. These assertions, much like those of Nostradamus, had little impact when they were made because they are too vague to be observationally tested. It was not until 1980 that Uruguayan astronomer Julio Fernández argued more convincingly that short-period comets might come from a disc-shaped region beyond Pluto, instead of from the more distant Oort Cloud as previously proposed. Even this made little stir, perhaps because of the dubious history of empty predictions made by Percival Lowell and others after him, such as Lowell's supposed observations of canals on the surface of Mars.



▲ Though impressive in appearance, Pluto is actually just another KBO, albeit a large one

The simple truth is that out of sight is out of mind, even for astronomers. Why think much about something that probably isn't even there? In the end, the Kuiper Belt was discovered not in response to any meaningful prediction but because, like Tombaugh, we were looking. Graduate student Jane Luu and I began our search in 1986, but rather than searching for a Kuiper Belt beyond Neptune, we were looking for any object beyond Saturn. We did not succeed until August 1992, when we found 1992 QB1, the second Kuiper Belt object (KBO) ever found. Six months later we found another object and then, over the next few years, the floodgates opened. We now know of about 1,600 KBOs, occupying a region vastly larger than the previously known planetary system.

After the flood

So, what have we learned since? Firstly, it is now clear that Pluto is a big KBO. Its peculiarly inclined, elliptical orbit suddenly makes sense – it is just like the orbits of innumerable other KBOs. Secondly, the Kuiper Belt is an enormous, deep-freeze repository holding the most primitive material in the Solar System. With temperatures only a few tens of degrees above absolute zero, even very volatile ices like carbon monoxide that cannot survive near the Sun are frozen solid in the Kuiper Belt. Icy objects leaving the belt are batted around the Solar System by the giant planets, leading to some being ejected to the interstellar medium never to be seen again, while others are captured by Jupiter. Ices in KBOs deflected near the Sun vaporise to create comets, with their familiar tails and coma.

Thirdly, we found that while the KBOs are very numerous, their combined mass is only a modest 0.1 Earth masses. This is so small that it would be difficult for the observed objects to have accreted, even over the age of the Solar System. The solution seems to be that the Kuiper Belt started out being much more massive than it is now, perhaps containing 20 or 30 Earth masses instead of 0.1, but then lost almost all of it. Where did it go?

The answer may lie in two other observational discoveries from the 1990s. We found that the Kuiper Belt is a thick disc, more like a doughnut than a sheet of paper, showing that the belt has been unexpectedly 'puffed up' since it formed. And we found, much to everybody's surprise, that the orbits of KBOs are divided into several distinct groups.

In one of these called the 'resonant KBOs', the orbital periods are simple variations of the 164.8 year orbital period of Neptune. For example Pluto's period (247.9 years) corresponds to two orbits for every three of Neptune's. Neptune and Pluto are said to be in the '3:2 resonance', along with thousands of other objects. Many other



FACTS AND FIGURES

The Kuiper Belt's vital statistics

- The Kuiper Belt begins 30 AU from the Sun, at the orbit of Neptune, and extends outwards in the plane of the Solar System for several thousand AU at least.
- Roughly 1,600 KBOs have been discovered since 1992.
- It's estimated there are roughly 100,000 objects larger than 100km in diameter in the Kuiper Belt, but only the largest and closest objects can be directly detected with present-day surveys.
- There are probably billions of bodies bigger than 1km.
- There are likely to be a few more objects the size of Pluto and there's room for something much larger, but not in the inner regions of the belt where a large body would be easy to detect.
- A few other large Kuiper Belt objects have been found such as Eris, Makemake, Haumea and Sedna.
- For every asteroid in the main belt between Mars and Jupiter, there are roughly 1,000 KBOs of similar size, spread over a volume of space at least 1,000 times that of the Asteroid Belt.
- The mass of all these objects added together is still only one-tenth of the Earth's mass. It's likely that many more bodies were present when the Solar System formed 4.5 billion years ago.

THE MOMENT OF DISCOVERY

Dave recounts the night he and Jane Luu found their first Kuiper Belt objects

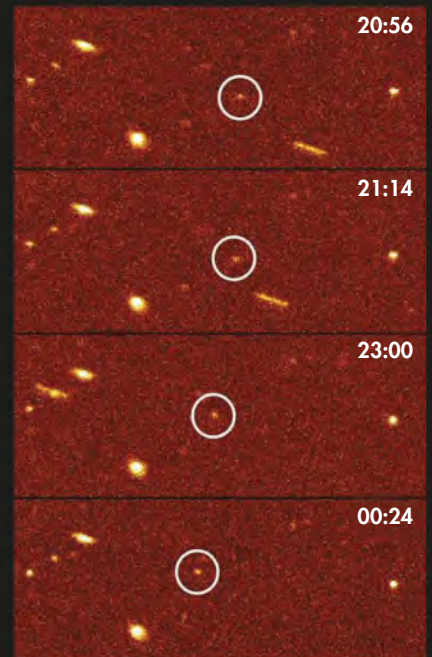


Dave and Jane searched for six years before their breakthrough

The trigger for the discovery of the Kuiper Belt was a simple question: why is the outer Solar System so empty? In the mid 1980s we knew that the inner Solar System was full of planets and asteroids, but the outer Solar System held only Uranus, Neptune and Pluto. I guessed that the answer might simply be that nobody had carefully looked. So, with graduate student Jane Luu, I started a search. We didn't know how difficult it would be or how long it would take. Six years later, sitting in the cold, thin air atop Mauna Kea in Hawaii using the 2.2m telescope, we noticed something.

We were taking four consecutive images of a given patch on the sky. By carefully

aligning the images and then flipping between them on a computer, we could distinguish moving objects from the thousands of stars and galaxies in each picture. We discovered uncountable numbers of asteroids this way. But we were interested in finding objects beyond Saturn, and we expected that these would creep much more slowly westward and would be faint. On 30 August 1992, at about midnight, we saw something that had exactly the characteristics we wanted. I noticed it by comparing the first two of four 20-minute exposures. Twenty minutes later, the third image confirmed the direction and slow motion and, 20 minutes after that, the fourth image left us briefly dazed with excitement. Quickly, we calculated the distance from the speed, then the size from the distance and the brightness. By the end of the night we knew that 1992 QB1 was about 250km in diameter and 50 AU from the Sun, by far the most distant Solar System body ever seen, and we realised that thousands of similar objects were waiting to be found. A few hours later and a mile below the summit, we celebrated with a big, greasy breakfast.



▲ The pair took many shots of 1992 QB1 that night; the streak is a faster moving asteroid

resonances (e.g. 2:1, 4:3, 1:1) are also occupied. But what made the Kuiper Belt so puffy, and why are there so many resonant KBOs?

All linked together

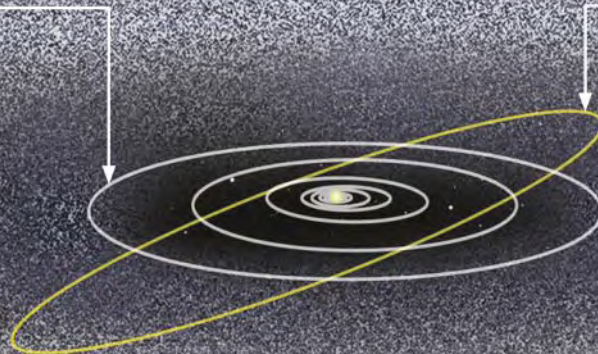
University of Arizona dynamicist Renu Malhotra gave us the answers. Resonant orbits prevent close, destabilising encounters with Neptune, allowing resonant KBOs to persist because they never tangle with 'the big guy'. Malhotra found resonant

▼ The Kuiper Belt is actually doughnut shaped; Pluto's inclined orbit is typical of other KBOs

KBOs were trapped because Neptune's orbit slowly expanded, from near 15 or 20 AU in the beginning to 30 AU now. As the planet scooted outwards, it trapped some of the planetesimals beyond it into resonant orbits. But the planets pull on each other by gravity so, if Neptune's orbit changed, they all changed. This 'radial migration' of the planets has revolutionised our thinking about the Solar System. In place of the old and rather boring clockwork Solar System in which the planets ►

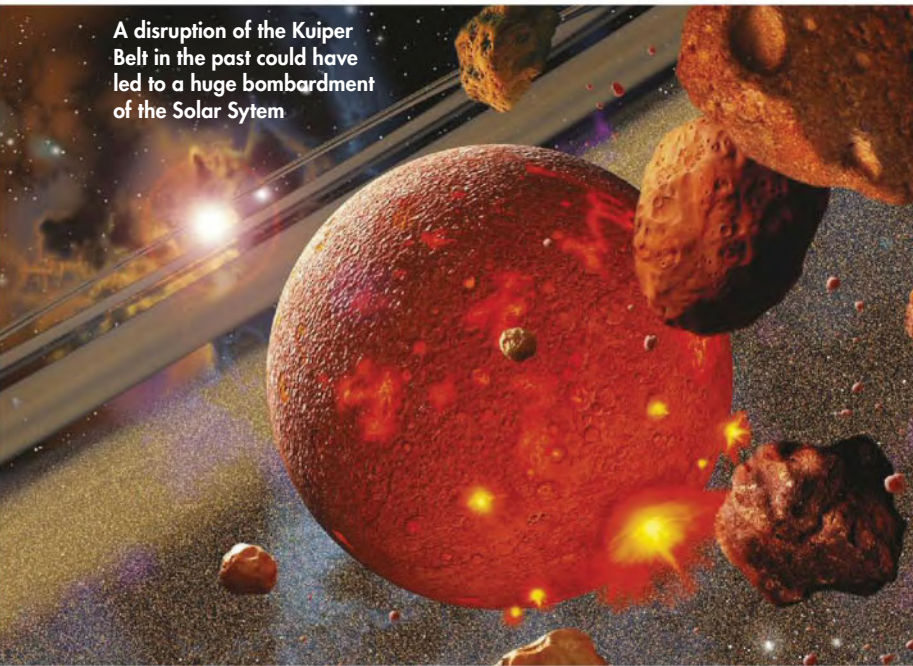
Neptune's orbit

Pluto's orbit



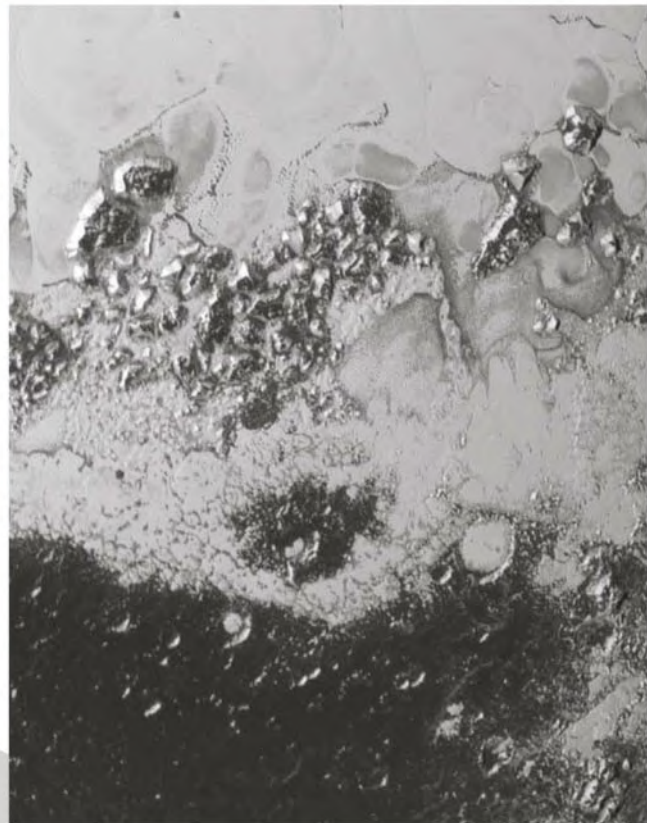
THE KUIPER BELT

A disruption of the Kuiper Belt in the past could have led to a huge bombardment of the Solar System



► held their orbits and moved predictably for billions of years, we now recognise a much more chaotic and harder to follow history. For example, simulations show that if radial migration caused two of the major planets to fall into a resonance of their own, this would

► Hopefully other KBOs will have landscapes as geologically diverse as Pluto's turned out to be



THE SUCCESS OF NEW HORIZONS

Pluto has taken on a new character in the wake of the flyby, and we don't even have all the data

As it drew near to Pluto, New Horizons answered the first of many questions, finally determining its diameter to be 2,370km, slightly larger than expected. Moving closer still, it sent back images showing a surface that is remarkably varied. Patches of light and dark material create striking boundaries, and parts of the surface look much younger than expected. Initial spectra showed that that methane-ice is frozen in place across the ground, but its abundance is patchy.

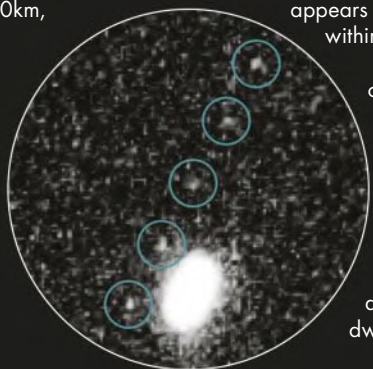
After flying past Pluto, New Horizons looked back at the dwarf planet, and saw that it is surrounded by a hazy atmosphere. The shot we

got was much brighter than expected, and showed it extending at least 83km above the surface with what appears to be clear layers within (see page 13).

At the moment most of the data we have is from compressed snapshots of the system. It will be 16 months until all the information gathered during the flyby is in and a full picture of the dwarf planet emerges. But the mission isn't over yet. Using its reserve fuel the craft will adjust its heading towards 2014 MU69,

a tiny and dim world only recently discovered with the Hubble Space Telescope. This rock is only 30-45km in diameter, and will be at a distance of 43.4AU when New Horizons flies by in January 2019.

▲ 2014 MU69, seen here being tracked by Hubble, is New Horizons' official next stop



have caused the entire architecture of the Solar System to be catastrophically upset. If this happened in the past then the initially massive Kuiper Belt would have been disrupted, showering the Solar System with debris and causing a swarm of giant impacts, perhaps recorded in the large basins that make up the 'face' on the Moon. All that would be left would be the puffed-up Kuiper Belt remnant that we see today.

As a result of all this, the significance of the New Horizons encounter with Pluto in July has changed since the mission was first imagined in the late 1980s. Instead of visiting the last, most peculiar planet, we find that we have visited a large but otherwise unremarkable Kuiper Belt object.

Even before this summer, we knew a lot about Pluto, including its mass, diameter and density, the composition of its surface ices, the existence, nature and variability of its atmosphere and the properties of its satellite system. But the New Horizons encounter has taken it to the next level by transforming Pluto from an astronomical object to a geological one, rich with surface detail that can never be detected from Earth. Hopefully, New Horizons will do it again in a few years time, when the spacecraft is set to pass a much smaller KBO only a few tens of kilometres across called 2014 MU69. **S**



ABOUT THE WRITER

David Jewitt is a professor at the University of California Los Angeles. He became interested in astronomy after watching a spectacular meteor shower in his native Enfield.

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IMAGING UNDER CITY SKIES

Jaspal Chadha reveals how
you can capture quality deep-sky
images under light-polluted skies

If you live in the city, the full Moon
is far from the only source of irritating
sky glare – but it's possible to capture
wonderful images all the same

For two years I have been attempting to image the night skies. There is just one problem: I live in London, one of the most light-polluted areas in the UK.

This makes it hard to achieve one of the main requirements for a good astro image – a high signal to noise ratio. While the best way to increase that ratio is to reduce the noise by imaging from a site with darker skies, there are still ways to do this from the middle of a city that mean it's still possible to capture a good image from under the urban lights.

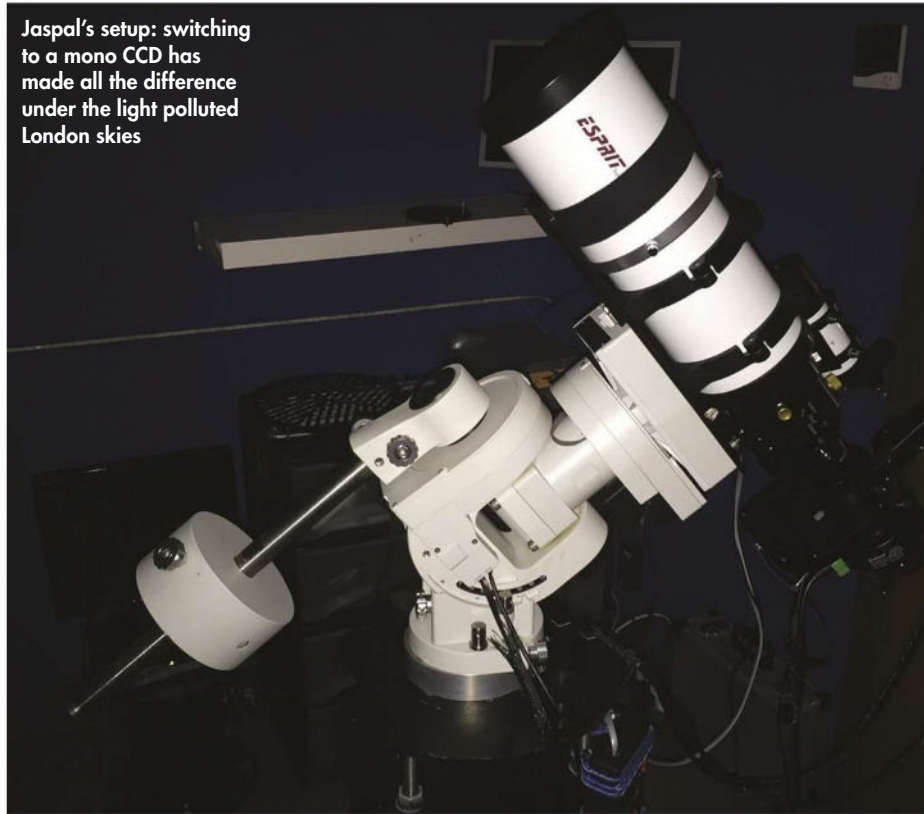
After months of trial and error I have finally come up with a setup that works for me. When I started off I used a DSLR and colour single shot CCD. The results weren't what I expected. The images lacked detail and were often filled with the orange glow of light pollution, despite my best attempts to reduce it. Even with exposures of four hours I wasn't happy with the amount of detail that I was managing to capture and trying to remove the glow was a long process that still didn't give me the results I wanted.

Sacrifice colour for clarity

Things improved when I switched to using a monochrome CCD camera. This keeps the main advantage of a CCD, its sensitivity. The more sensitive the camera, the shorter the exposure required to detect faint detail. CCD cameras have a greater dynamic range than DSLR cameras, meaning there is a larger range of luminosity it can detect. The CCD can more easily capture both faint and bright detail in a single exposure, rather than needing several images to bring out different details.

However, a mono CCD only detects the brightness of the light, not its colour. To bring out the colour of images you have to use filters. In normal colour imaging, three filters are used to separate the primary colours of the visual

Jaspal's setup: switching to a mono CCD has made all the difference under the light polluted London skies

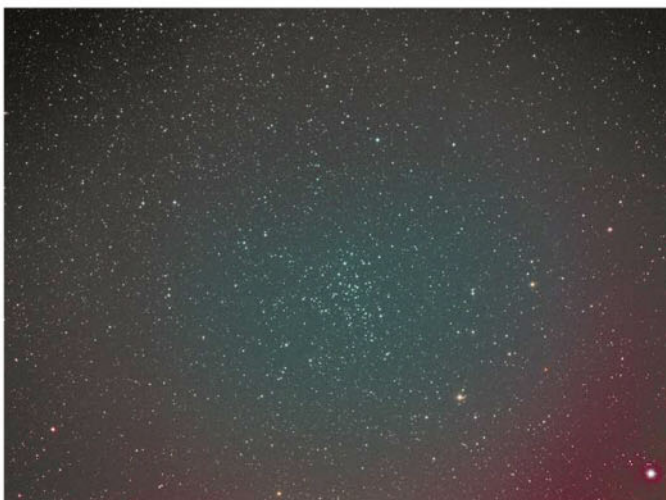


“My images lacked detail and were often filled with the orange glow of light pollution”

spectrum. Red, green, and blue (RGB) filters are designed to approximate the colour sensitivity of the human eye, so that the resulting image is true colour.

When using RGB filters to create a broadband image, all types of wavelengths are captured across the entire visible spectrum so this picks up a lot of light pollution from the surrounding city lights. This is usually most visible as green and magenta gradients in the images. To reduce this I use a simple CLS CCD light pollution filter.

There are a few things to remember when using light pollution filters in general. First is that they ▶



▲ The night sky before (left) and after (right) processing – the amount of sky glow that can be removed with editing software is tremendous

© PAUL CARSTAIRS/ALAMY STOCK PHOTO, JASPAL CHADHA X 3

► are not 100 per cent fool proof when it comes to light suppression. These filters are helpful, but they have their drawbacks. All of them are designed to block out only particular wavelengths of light and there's one overriding factor to consider when deciding how effective they will be for you. They're designed to block the wavelengths emitted by low pressure sodium vapour lamps – the orange type. If the area you observe in is lit by newer LED lamps then light pollution filters will be useless. They also cut down the total light getting to the sensor, so the exposures required will be longer. However, they should increase the ratio of useful image information compared to background glow, so overall should result in an improvement.

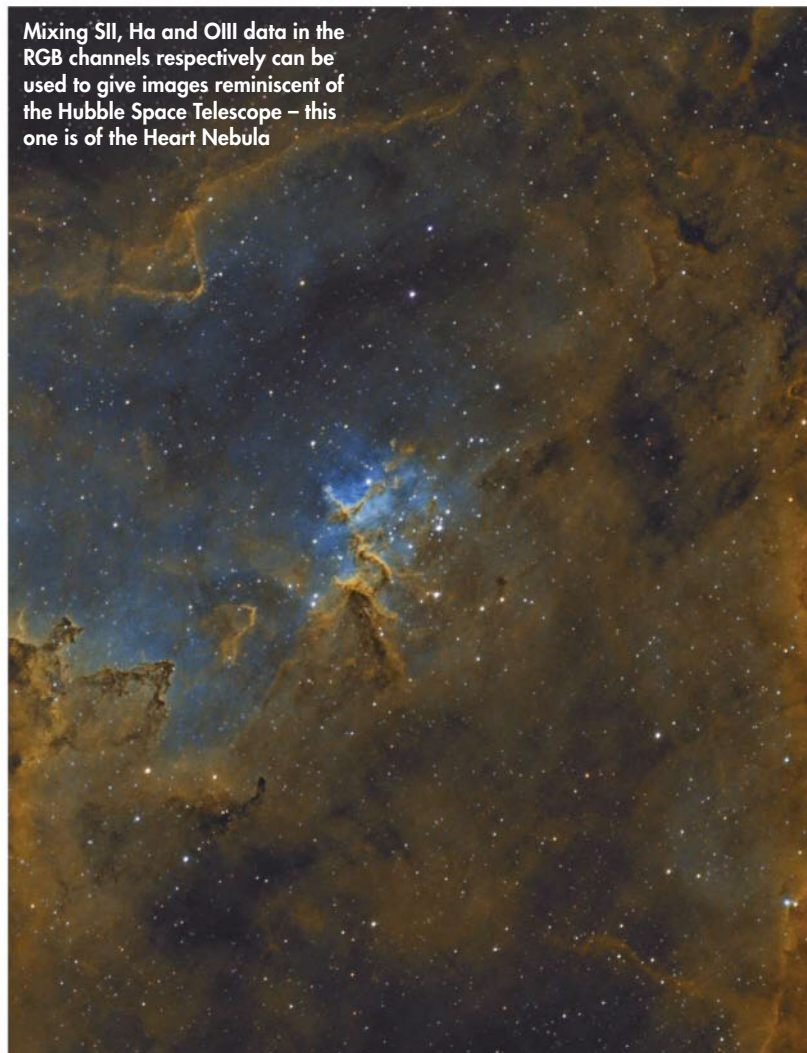
Go deeper by narrowing down

For those times when I want to bring out the finer detail of a deep-sky object, I add narrowband filters: the light pollution filter's green tint is easy to remove in photo editing software during processing. These enhance the contrast of emission objects by accepting only a narrow range of wavelengths around the emission lines of certain gasses within the objects, such as hydrogen-alpha (Ha), oxygen (OIII), sulphur (SII) and others.



Light pollution filters are designed to block the orange glow of sodium streetlamps (left), but won't affect LED lights (right)

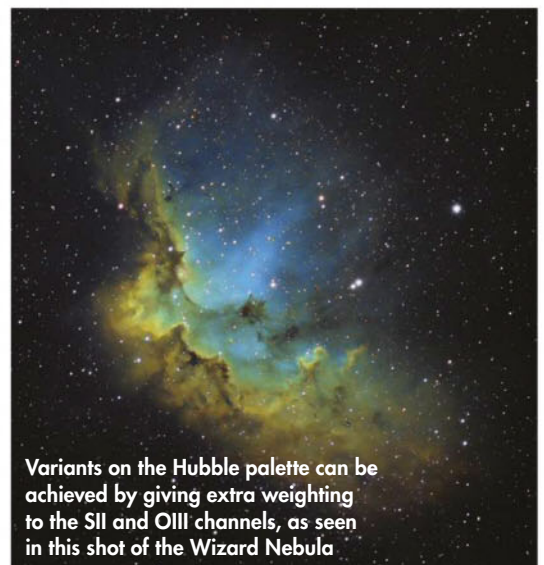
Mixing SII, Ha and OIII data in the RGB channels respectively can be used to give images reminiscent of the Hubble Space Telescope – this one is of the Heart Nebula



Another Hubble palette rendition, this time of open cluster Melotte 15 within the Heart Nebula



Variants on the Hubble palette can be achieved by giving extra weighting to the SII and OIII channels, as seen in this shot of the Wizard Nebula





During post-processing the data from each emission line is assigned a certain colour band – red, green or blue – and these are combined later in a graphics editor to create the most stunning images.

As these filters only pick up a tiny portion of the light, they can be used to take astrophotos even when the Moon is up as well or from locations usually plagued by light pollution. Narrowband filters commonly come with a bandwidth of 5nm or 3nm at the emission line they let through; you can expect to pay a higher price for the lower bandwidth filters.

Much time and effort will be required to capture data from all three filters. So little light gets past the filter that imaging requires very long exposure times. Typically I'll spend at least three to four hours imaging time on each filter, with some



▲ Planetarium programs like Stellarium can help you to plan your sessions

FORWARD PLANNING

1. Plan your imaging in advance using a planetarium program such as Stellarium (www.stellarium.org) to work out where your target is going to be in the sky and how much time you have to capture it. This will also help you work out where the best place in your garden or observing site will be to both avoid light pollution and get the best view.

2. Image when your desired object is just past the meridian line in the sky. This will ensure you have the best sky conditions and will help shy away from light pollution.

3. Invest in a decent mount that will allow you to track for a longer period if you are aiming to do long-exposure astrophotography.

“The most rewarding results come from the hydrogen-alpha filter. The image is readily visible and has much detail”

◀ The Bubble Nebula: OIII (top) and SII (middle) filters produce dim and noisy images, but when combined with Ha data the result (bottom) is great

single exposures of up to an hour. The most rewarding results come from the Ha filter. The image is readily visible and has much detail. The OIII and SII filters produce dim, noisy images that are frustrating to work with, but are needed for a complete image.

Staying on target

Keeping the telescope on track when narrowband imaging takes some practice too. I use an autoguider, and finding a stable guide star can be a challenge thanks to the fact that so little light reaches the guide camera's sensor. Some narrowband imagers choose to use a separate camera on a guidescope. This has several advantages, the biggest being that since the guide CCD is not looking through the narrowband filter, the stars appear considerably brighter and finding a suitable guide star is easy.

The drawback to a guidescope though is flexure, where different parts of the telescope setup move by different amounts over the course of the night. This means that the main telescope may not be perfectly aligned with the guidescope during the course of the exposure. I use an off-axis guider ▶

► that allows you to guide your telescope through the same optics that are taking the picture. This eliminates any possibility of guiding error.

However, the main difference between narrowband and broadband images comes when you combine the colours for the first time using image editing software. Generally I use the standard Hubble palette combination where SII is red, Ha is green and OIII is blue. Since the Ha is usually a much stronger emission line, the result comes out very green. So it's a good idea to assign the SII and OIII a stronger combine factor, or do an equivalent in Photoshop to 'push' the SII and OIII data before combining them. Even when that is done, it's likely you'll want to do more colour adjustments, such as adding a Selective Colour adjustment layer, before the results become pleasing.

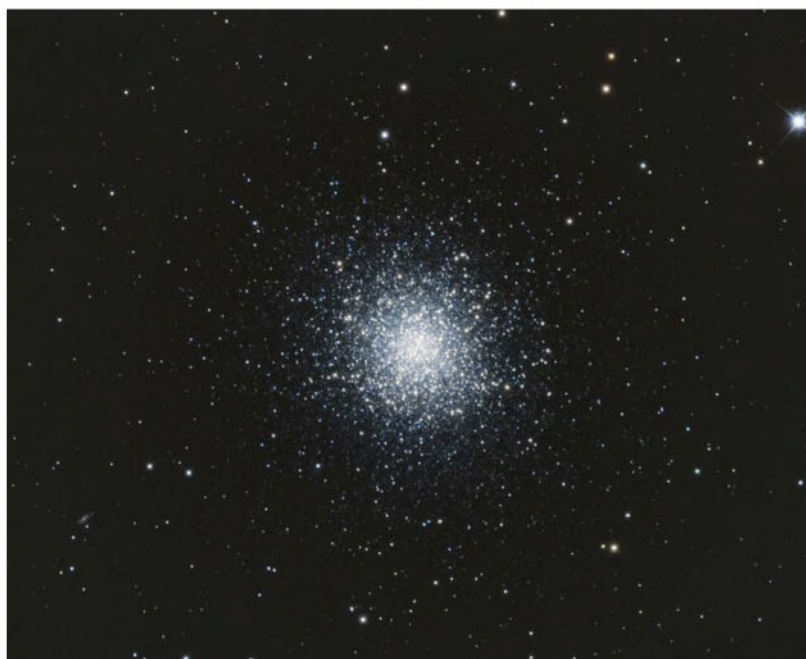
Though I try to cut down on light pollution, there's always a little that gets through. To cope with this, I use powerful program called Gradient Xterminator (www.rc-astro.com/resources/GradientXTerminator) when processing data. This Photoshop plug-in destroys light wash and amplifier glow from surrounding lights that may have been introduced while imaging.

Finally, once all of this is done I arrive at my final image. It might take a bit of work, but you would be amazed with what you can accomplish even under the skies of a city. **S**



ABOUT THE WRITER

Jaspal Chadha has been an astro imaging enthusiast for two and a half years. He captures the sky from his garden in London, where he has to overcome the heavily polluted skies.



▲ Even from a polluted sky it's possible to capture great deep-sky shots; clockwise from top: the Whirlpool Galaxy, the Dumbbell Nebula and globular cluster M13

REDUCING LIGHT POLLUTION

Hiding away from light pollution is much more effective than editing it out afterwards

Shielding your equipment from stray light can be as simple as adding a cardboard cuff to the end of your scope, or by extending the dew shield.

A lot of stray or unwanted light these days comes from security lights. If you have them, turn them off while observing. If your neighbour's security lights are troublesome, politely ask if they can be turned off while you observe. An offer to show the neighbours what you are looking at can work wonders and you never know, you might convert them to your hobby.

Stray light also reduces as the night goes on. More people head to bed, turning off their lights as they go, and some local authorities turn street lighting down or off after midnight. If you are able to stay out late, you'll probably find that after midnight the amount of stray light

around seems to be less than earlier in the evening.

Even if you have streetlights shining into your garden, it's usually possible to find a spot that's not illuminated by them, giving a good view of the sky. Getting into the shadow of a brick wall or a tree can help here, though this can block your view of a large part of the sky, so you may need to hunt around for the best spot in your garden.

One of the most difficult forms of light pollution comes from artificial light being shone directly into the sky and reflecting back off dust and water vapour, filling the sky with a haze of light. High humidity or prolonged dry spells when dust can be thrown up into the atmosphere will seem to make the situation worse. Check weather reports and wait for stable conditions with low wind speeds to get the darkest skies.



▲ Jaspal's observatory is at the back of his garden, where trees help to shield it from light pollution

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The 3D planetarium allows viewers to 'fly' through the cosmos

THE UNIVERSE IN

3D

At-Bristol's planetarium has recently been updated, making it one of the highest resolution 3D cinemas in the world, writes **Elizabeth Pearson**

Flying through the rings of Saturn, particles of ice and rock spinning around you, is a fantasy many astronomers have had while staring at the distant planet through an eyepiece. But few thought they would ever get to see it. Yet this was just one of the sights I was treated to when I paid At-Bristol's newly updated 3D planetarium a behind-the-scenes visit.

The flight was part of their seasonally updated stargazing programme, showing what can be seen in the sky that night. But rather than simply walking viewers through the constellations and planets, the 3D planetarium allows you to fly through



The planetarium sits within a mirrored ball in Bristol's Millennium Square

the Solar System, and visit the stars and planets up close as they appear to leap from the screen towards you.

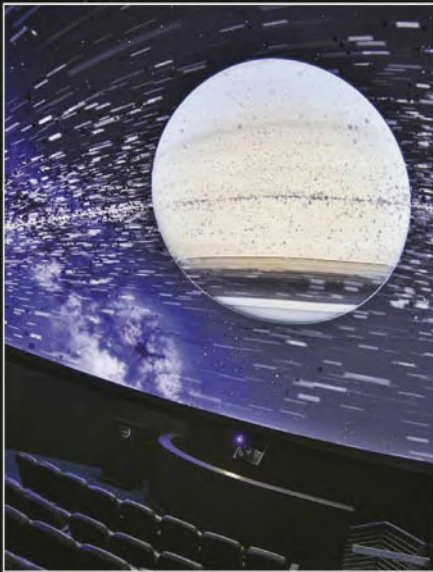
"The Universe is 3D," says Lee Pullen, At-Bristol's planetarium manager. "Planets aren't circles, they are spheres. Planets, orbital paths, the structure of the Solar System – it just works better in 3D."

The magnificent views are generated by two 4K projectors – one covering the front of the dome, the other covering the back – transmitting at 120 frames per second. This is double what the eye can see, but it's needed because

the system uses active 3D. "The glasses have infrared sensors that sync up with the whole system," says Pullen. "The lenses are LCD screens that turn off and on incredibly fast."

The flickering lenses are timed with the images on the dome flashing back and forth between the left and right eye images to create the illusion of 3D.

"The resolution combined with the high frame rate means that every second we put out 1.6 billion pixels onto the dome, which we think makes us the highest resolution cinema in the UK," says Pullen.



▲ While flying through the rings of Saturn, the particles appear to swirl around your head



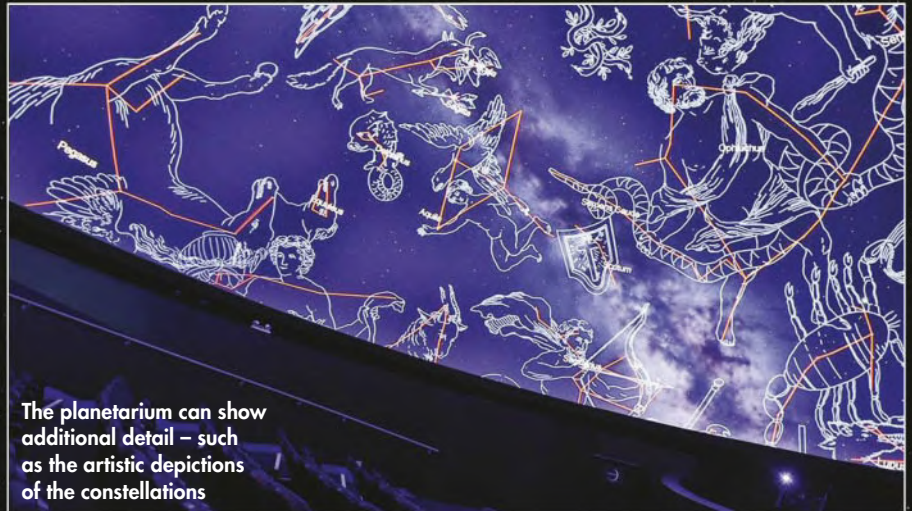
▲ This computer system allows complete control over the planetarium, and the Universe

This impressive projection system is hooked up to an equally impressive software suite. The shows put on at the dome are not just pre-rendered films. They are controlled by the presenters on the fly as they go through the show. The entire Galaxy and beyond is simulated in the planetarium software, requiring 17 computers and 15 graphics processors to run.

Flight of the navigator

"It's not just a film," says Seamus Foley, the planetarium media production officer. "It's essentially a huge videogame of the Universe. What you see is the presenter pressing buttons on an iPad, but they could potentially go anywhere in the Universe at any time. I think that's one of the great things about planetariums. You can say fly to Saturn, and you fly to Saturn from anywhere in the Universe."

I was lucky enough to be able to take control of the planetarium, making a jaunt to the Helix Nebula in Aquarius. It was here the combination of 3D and high resolution really became apparent.



The planetarium can show additional detail – such as the artistic depictions of the constellations



▲ The planets are not computer generated – they are based on real spacecraft data

Rather than simply seeing a flat image of the nebula, the program used the latest observations and simulations to create a 3D model we were able to fly through.

The team at At-Bristol hope that one-day they can team up with researchers of all disciplines to help them visualise their data, so they can be part of making scientific discoveries, as well as teaching about them.

"In the future we might be able to stream 4K frames in real time from the University of Bristol nearby, so you can have a supercomputer processing visualisations of molecular simulations, for example, and it turns up in the planetarium," says Foley.

The planetarium software already keeps abreast of the latest advances in space science – it is regularly updated with new observations. When New Horizons flew past Pluto, the team at the dome were among the first to see the 3D renderings of the dwarf planet.

During the tour of our Solar System, we landed on Olympus Mons on Mars, but the landscapes surrounding us weren't computer-generated estimates of what the surface should look like: they were based on the latest scans of the planet.

Over the course of this year around 130,000 people will have sat under the dome and landed on Mars or flown through the rings of Saturn as the dome takes them to places they have never seen before. The prime purpose of the planetarium is to educate, to open up people's minds to the wider Universe that hides in the night sky.

"We have people coming out and they are absolutely buzzing," says Pullen. "Today one lady came out of the show and confessed she'd found the experience so emotional that she'd wept tears of joy in the show. Often people are just amazed. They had no idea that there was so much out there to be able to find." **S**



Find out more about the planetarium and the At-Bristol science centre at www.at-bristol.org.uk



ABOUT THE WRITER

Dr Elizabeth Pearson is *BBC Sky at Night Magazine's* news editor. She gained her PhD in extragalactic astronomy at Cardiff University.

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The Sky Guide November

The beautiful Pleiades open cluster takes centre stage this month. Always a joy to behold, the cluster stars resemble sparkling diamonds scattered on black velvet. A perfect binocular object, the cluster is also a regular port of call for astrophotographers.



**Written by
Pete Lawrence**

Pete Lawrence is an expert astronomer and astrophotographer with a particular interest in digital imaging. As well as writing *The Sky Guide*, he appears on *The Sky at Night* each month on BBC Four.

PLUS

Stephen Tonkin's
BINOCULAR TOUR

Turn to page 58 for six
of this month's best
binocular sights

PETE LAWRENCE

Highlights

Your guide to the night sky this month



This icon indicates a good photo opportunity

1 SUNDAY

Eclipsing binary star Lambda (λ) Tauri reaches minimum brightness at 23:12 UT. Its period is 3.95 days, with the eclipse lasting for 14.2 hours, during which the brightness dips from mag. +3.4 to +3.9. Other well-timed minima occur on the 5th at 22:06 UT, the 9th at 21:00 UT and the 13th at 19:48 UT.

2 MONDAY

Brilliant Venus is best seen low in the east between 03:00 and 05:30 UT. Shining away at mag. -4.2, Venus appears to have a close companion in the form of mag. +1.7 Mars, just 50 arcminutes northeast.

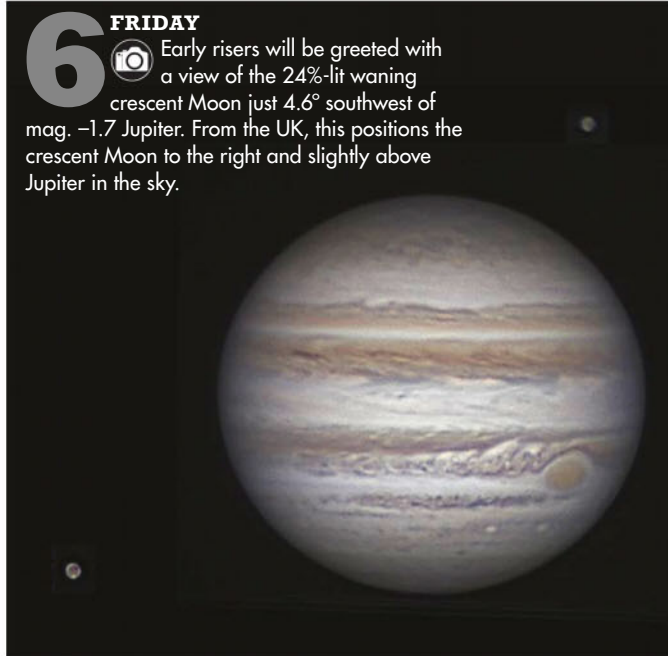
3 TUESDAY

Venus and Mars continue to appear close to one another in the early morning sky, low in the east before dawn. This morning both planets have an apparent separation of 41 arcminutes. The apparent close separation is a line of sight effect – Mars is three times farther from Earth than Venus is.



6 FRIDAY

Early risers will be greeted with a view of the 24%-lit waning crescent Moon just 4.6° southwest of mag. -1.7 Jupiter. From the UK, this positions the crescent Moon to the right and slightly above Jupiter in the sky.



7 SATURDAY

The morning show continues, with Mars, Venus and a 17%-lit waning crescent Moon creating a tight triangle around mag. +3.6 Zavijava (Beta (β) Virginis). Look for them in the east-southeast.

9 MONDAY

Mag. +1.7 Mars and mag. +3.6 Zavijava (Beta (β) Virginis) are just 48 arcminutes apart this morning. Again, this is a line of sight effect – at a distance of 37.4 lightyears, the star is over one million times farther away than Mars.

11 WEDNESDAY

The constellation lying overhead at midnight is Perseus. Its brightest star, mag. +1.8 Mirphak (Alpha (α) Persei), is half-surrounded by a semicircle of stars to the southeast. These are visible with the naked eye, but binoculars bring them out best.



12 THURSDAY

Tonight is the official peak of the Northern Taurid meteor shower which has a zenithal hourly rate of five meteors per hour. Enhanced Taurid activity has been predicted for this year. See page 50.

13 FRIDAY

The planets continue to dazzle in the morning sky. This time it's the turn of mag. -4.2 Venus, which is 5 arcminutes from mag. +3.9 Zaniah (Eta (η) Virginis) at 05:20 UT, but continues to close to a separation of just under 4 arcminutes as the sky starts to brighten.

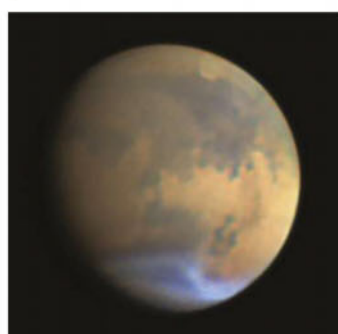


17 TUESDAY

The Leonid meteor shower reaches its peak tonight. The good news is that the shower radiant, which lies in the Sickle asterism, rises as the Moon sets. See page 50.

21 SATURDAY

Mars passes close to the mag. +3.9 Zaniah (Eta (η) Virginis) this morning. The planet and star will appear separated by just 7 arcminutes. Look for them in the east-southeast.



22 SUNDAY

The Alpha Monocerotid meteor shower reaches its peak at 04:25 UT. Its zenithal hourly rate is a low five meteors per hour, but 20 years ago it topped out at 420 meteors per hour for a five-minute period. The next outburst isn't expected until 2043 but observations are always worthwhile.

27 FRIDAY

Comet C/2013 US10 Catalina may be visible in the early morning sky close to mag. +4.5 Lambda (λ) Virginis. You'll need a flat horizon to spot the 9th-magnitude comet, but the good news is that it is getting higher in the UK's morning sky.

4 **WEDNESDAY**
Mag. +5.7 Uranus is currently making a right-angled triangle pattern with the stars 80 and 73 Piscium (mag. +5.5 and +6.0 respectively). In turn, this triangle lies 2° south of mag. +4.3 Epsilon (ε) Piscium.

5 **THURSDAY**
The 'Winking Demon', eclipsing binary star Algol (Beta (β) Persei), reaches minimum brightness at 03:42 UT. The star normally shines at mag. +2.1, but during its primary eclipse it fades to mag. +3.4. Its period is two days, 20 hours and 49 minutes with minimum brightness lasting for 9.6 hours.

10 **TUESDAY**
 The Moon is a thin sliver just 1%-lit this morning. See if you can spot it low down in the east-southeast from just after 06:00 UT.

With the Moon now out of the way, this is a great time to try our deep sky and binocular tours. Turn to pages 56 and 58 to take our journeys around the November night sky.

30 **MONDAY**
 The beautiful Pleiades open cluster is currently visible in dark skies 30° up in the east at 19:00 UT. This is an ideal time to look at this beautiful object as the Moon will still be below the horizon. Turn to page 60 for details and advice on how to image this spectacular cluster.

What the team will be observing in November



Pete Lawrence "I'm going to be on the lookout for some spectacular Taurid fireballs in the second week of November. This should be a great taster for the peak of the Leonids, which is on the 17th."



Paul Money "Mars and Venus are in conjunction in the morning sky on the 3rd, then the crescent Moon joins them on the 7th – I'll be hoping to image and view them all in close proximity."



Stephen Tonkin "Cassiopeia is high in the sky, and it's always rewarding to leisurely scan this region with binoculars to see its beautiful clusters, knots and chains of stars."

Need to know

The terms and symbols used in *The Sky Guide*

UNIVERSAL TIME (UT) AND BRITISH SUMMER TIME (BST)

Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT.

RA (RIGHT ASCENSION) AND DEC. (DECLINATION)

These coordinates are the night sky's equivalent of longitude and latitude, describing where an object lies on the celestial 'globe'.

HOW TO TELL WHAT EQUIPMENT YOU'LL NEED



NAKED EYE

Allow 20 minutes for your eyes to become dark-adapted



BINOCULARS

10x50 recommended



PHOTO OPPORTUNITY

Use a CCD, planetary camera or standard DSLR



SMALL/MEDIUM SCOPE

Reflector/SCT under 6 inches, refractor under 4 inches



LARGE SCOPE

Reflector/SCT over 6 inches, refractor over 4 inches



Getting started in astronomy

If you're new to astronomy, you'll find two essential reads on our website. Visit http://bit.ly/10_Lessons for our 10-step guide to getting started and http://bit.ly/First_Tel for advice on choosing your first scope.

DON'T MISS...

3 top sights

👁 November meteors

WHEN: As specified



A true Leonid meteor will appear to emanate from the shower's radiant, which sits within the Sickle asterism

THE LEONID METEOR shower peaks mid-month, a shower famous because of the periodic 33-year interval storm-level outbursts it has shown in the past. The storm of 1833 was so dramatic, producing 1,000 meteors per minute, that it's generally regarded as the event that gave birth to modern meteor astronomy.

Analysis led to a prediction that storm-level activity would return in 1866. This proved accurate, with 5,000 meteors per hour seen. The 1899 return turned out to be a damp squib caused by the meteoroid stream having been perturbed by Jupiter and Saturn. In 1933 the shower delivered hundreds of meteors per hour at peak; 1966 was tentatively predicted to produce similar rates, but reached storm levels of 40-50 meteors per second for 15 minutes.

The 1999 return was given a precise prediction that proved,

if anything, on the safe side, with 3,000 meteors per hour reported. The shower's parent comet, 55P/Tempel-Tuttle passed through perihelion in 1998, an event that enhanced the amount of dust eventually spread around the comet's orbit to produce the Leonids.

We're now mid-way through the 33-year cycle and this year's zenithal hourly rate is expected to be 15 meteors per hour. Two peaks have been predicted; one at 21:00 UT on the 17th and one at 04:00 UT on the 18th, so a watch through the night should be interesting.

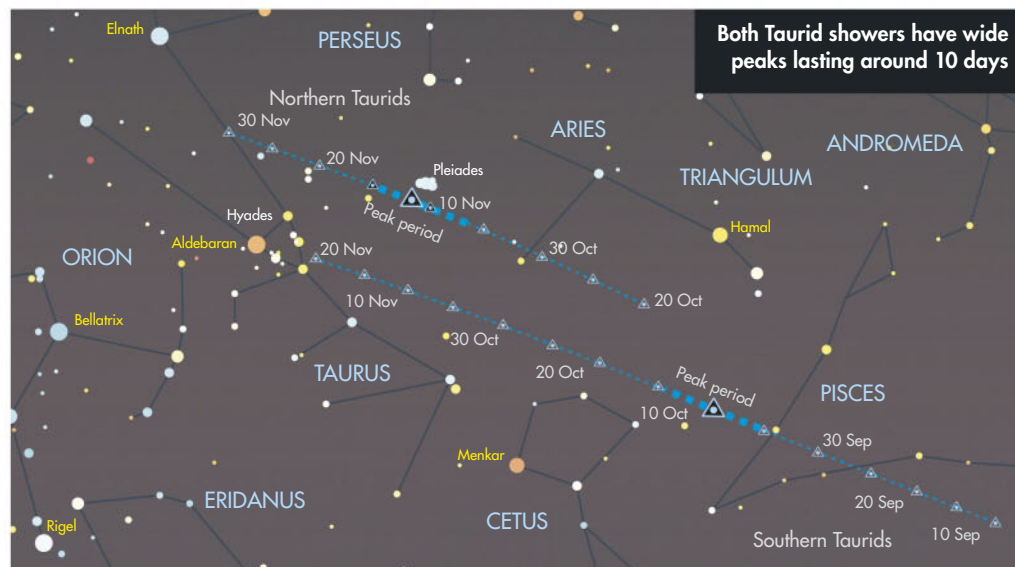
! NEED TO KNOW

The zenithal hourly rate of a meteor shower is the expected number of meteors seen under perfect conditions with the radiant point of the shower overhead.

The 34%-lit waxing crescent Moon sets around 21:30 UT on the 17th so won't present a problem. The shower radiant is within the head of Leo, inside the Sickle asterism. To qualify as a Leonid meteor, the trail must point back to the radiant. Leonids are swift movers, entering the atmosphere at 71km/h. This can make them challenging to photograph but it's always worth setting up just in case a bright Leonid fireball occurs.

In addition to the Leonids, the Northern Taurids peak around 12 November. This shower has a low zenithal hourly rate of five meteors per hour, but this year there is a prediction out that the part of the Taurid stream that we're passing through may produce bright events.

The best time to observe the Taurids is during the first half of November. The peak is typically broad lasting up to 10 days and the Moon is conveniently new on the 11th.



Morning planet show

WHEN: All month

THERE ARE NO bright planets on view in the evening sky at the moment but if you're prepared to stay up all night – or, perhaps more sensibly, wake up early – you'll be able to see that they are putting on quite a show in the morning.

The massing that occurred last month is still there, with Venus, Jupiter and Mars acting as the core of the display. On the 1st, Mars and Venus will appear close together, separated by about 1° . They will be located on the border between Leo and Virgo, with Jupiter a little farther into Leo close to the mag. +4.1 Sigma (σ) Leonis.

Venus and Mars continue to close in on one another, being just 40 arcminutes apart on the morning of 3 November. By the 6th the pair will have separated, appearing 1.5° apart. Look 15 arcminutes to the south of Venus at this time and here you'll see the mag. +3.6 Zavijava (Beta (β) Virginis). At mag. -4.2, Venus will completely dominate the star.



On the 7th, Venus, Mars and the waning crescent Moon form a triangle around Zavijava

A 24%-lit waning crescent Moon enters the scene from the west on the morning of the 6th, lying a little under 5° from mag. -1.7 Jupiter. The next morning, the now 17%-lit crescent Moon, Venus and Mars form a tight triangle with Zavijava in the middle.

All three planets are in a line by 13 November, with Jupiter appearing

just 42 arcminutes from Sigma Leonis, and Venus sitting 5 arcminutes from mag. +3.9 Zaniah (Eta (η) Virginis) at 05:00 UT. The gap continues to close until 06:30 UT, when both objects are a little under 4 arcminutes apart. On the 18th, Venus is just over 1° to the south of the close double star Porrima (Gamma (γ) Virginis).

Comet C/2013 US10 Catalina

WHEN: Last week in November

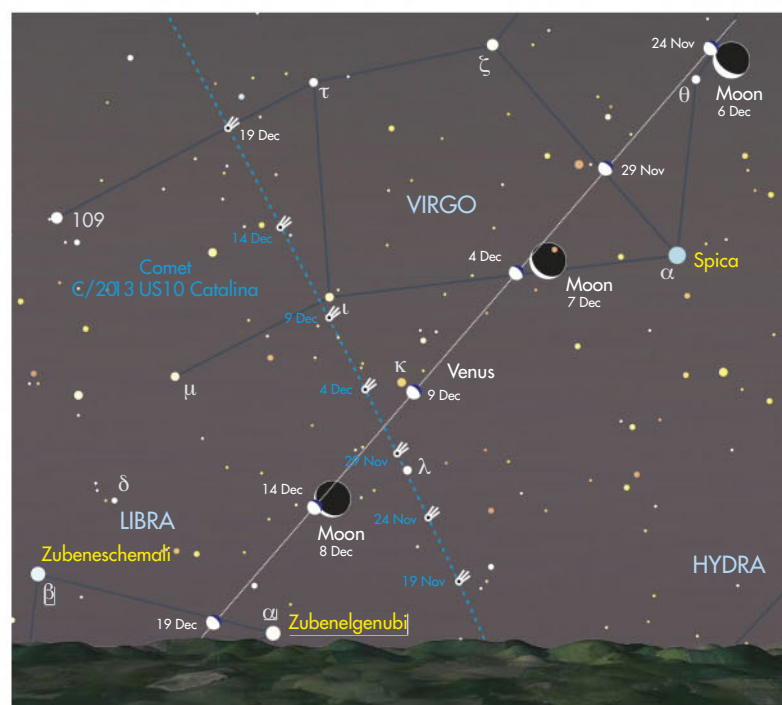
COMET C/2013 US10 Catalina has been putting on a bit of a show lately, but sadly it has only been visible from the southern hemisphere. The comet is currently quite bright but remains awkwardly positioned at the start of November, some distance south of the Sun.

However, as we head further into the month, the comet and Sun appear to sidestep one another, with the comet heading further north as the Sun slips further to the east. On 20 November, the comet will be to the west of mag. +5.2 Zubenelgenubi (Alpha (α) Librae), so if you're up watching the morning planet show

remember to do a binocular sweep low along the southeast horizon about one hour before sunrise.

The situation continues to improve towards the end of November when the comet will be close to mag. +4.5 Lambda (λ) Virginis and visible, albeit at an altitude of around 5° , in a truly dark sky.

Best of all, the comet is slowly brightening and during the end of November when it's at its best for the month, it should be naked eye at around mag. +4.7. This is expected to be the peak magnitude for C/2013 US10 Catalina, but it should remain above mag. +5.0 right through to the end of December.



The comet passes through Libra into Virgo, brightening all the way

The planets

PICK OF THE MONTH

JUPITER

BEST TIME TO SEE: 30 November

05:30-06:00 UT

ALTITUDE: 40°

LOCATION: Leo

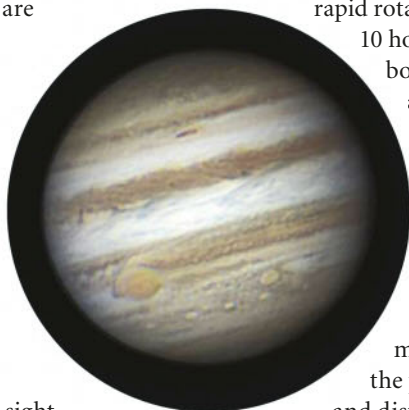
DIRECTION: South-southeast

FEATURES: Squashed disc, main belts, Great Red Spot, Galilean moons

EQUIPMENT: 4-inch or larger scope with low, medium and high power eyepieces

JUPITER IS IN Leo and sits very close to the star that marks the lion's rear paw, mag. +4.1 Sigma (σ) Leonis. On 15 November, star and planet are separated by 39 arcminutes. Jupiter's brightness and apparent diameter are on the rise. At the start of November its apparent diameter is 33 arcseconds and this increases to 35.6 arcseconds by the end of the month. Its brightness increases from mag. -1.8 to -2.0 over the same period.

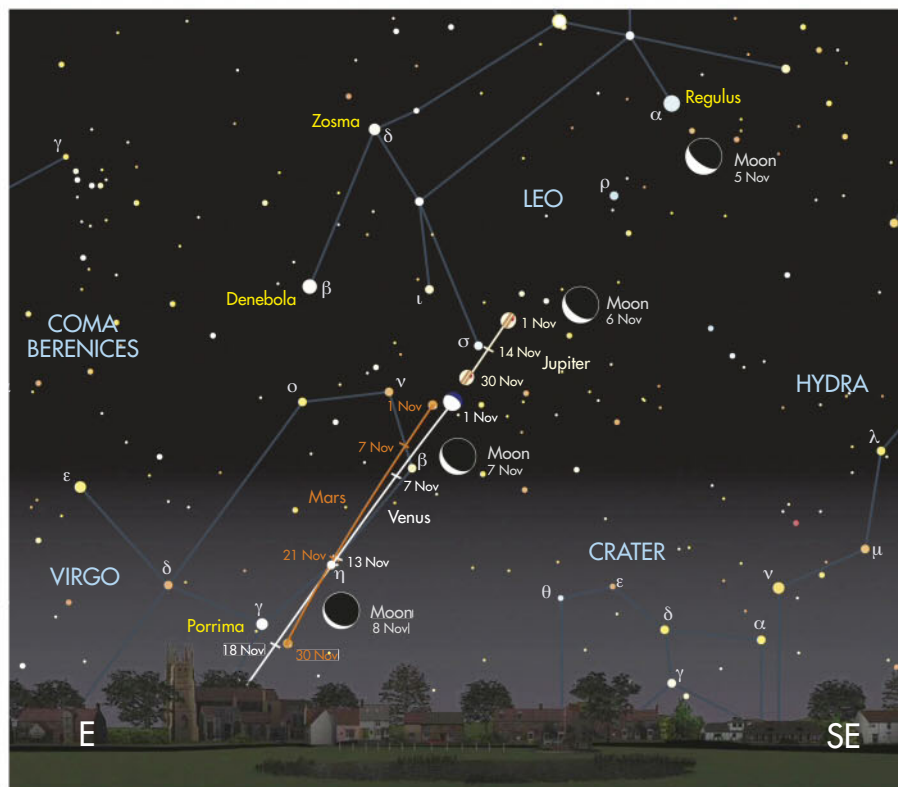
Through a telescope Jupiter is a magnificent sight. The planet's disc appears squashed at the poles. This is a real effect caused by Jupiter's



High powers will reveal the main belts have rough edges

rapid rotation period of less than 10 hours, causing its gaseous body to expand outward at the equator.

This is a planet that really rewards patient viewing. Take your time looking at its disc and more detail will slowly come into vision. Using a low magnification will show the planet's disc as a bright and distinctly squashed. The Galilean moons will be on view too, but how many will depend on where they are in their orbit



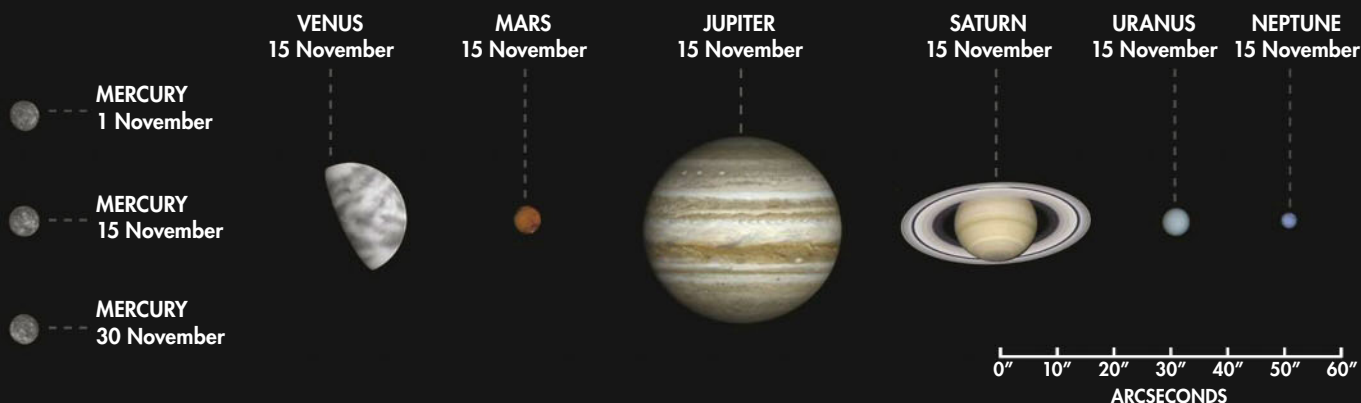
Jupiter moves through the morning sky with Venus – see page 51 for tips on viewing them together

– see our Jovian moon locator graphic on the opposite page.

The two main belts running parallel, north and south of the equator, will also be visible in a low power eyepiece. Once you've enjoyed then, increase the magnification by two or three times. The contrast will drop off as the magnification increases and effects from the turbulent atmosphere will be more evident. However, with care it should now be possible to see other features on the disc. These include irregularities along the edges of the main belts and the fantastic Great Red Spot. Jupiter's position continues to improve making this a great month to start serious observations of this giant planet.

THE PLANETS IN NOVEMBER

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



VENUS

BEST TIME TO SEE:

1 November 06:00 UT

ALTITUDE: 28°

LOCATION: Virgo

DIRECTION: Southeast

The 'Morning Star' earns its title this month. On the 1st, Venus rises 4.5 hours before the Sun, meaning that it can be seen against a dark sky background at a decent altitude. At mag. -4.2 it's going to be a hard target to miss, completely outshining any other object in the east-southeast part of the sky apart from the Moon. A beautiful crescent Moon enhances the view on 6-8 November – see page 51.

Telescopically, the planet has now entered its waxing gibbous phase, the phase increasing from 54% at the start of the month, to 67% at the end. Its distance from Earth is increasing too, meaning that its apparent diameter shrinks from 22.7 arcseconds to 17.4 arcseconds during the month.

URANUS

BEST TIME TO SEE:

1 November 22:30 UT

ALTITUDE: 43°

LOCATION: Pisces

DIRECTION: South

Uranus is visible for most of the night all month. Located in Pisces, its mag. +5.7 dot sits amongst a number of stars of similar brightness to the south of mag. +4.3 Epsilon (ε) Piscium. On the 22nd, the 86%-lit waxing gibbous Moon sits 1.75° south of the planet. Through a telescope, Uranus shows a 3.6-arcsecond disc that appears greenish in colour.

NEPTUNE

BEST TIME TO SEE:

1 November 20:00 UT

ALTITUDE: 27°

LOCATION: Aquarius

DIRECTION: South

Neptune is well positioned and at month end just manages to pass its highest position in the sky, due south,

after darkness has fallen.

You'll need binoculars at least to find its mag. +7.9 dot, 1.3° northeast of the mag. +4.8 star Sigma (σ) Aquarii.

Viewing Neptune through a telescope reveals it to look quite unlike a star. Although small, its 2.3-arcsecond disc has a distinctly blue hue to it.

MARS

BEST TIME TO SEE:

30 November 06:30 UT

ALTITUDE: 30°

LOCATION: Virgo

DIRECTION: South-southeast
Mars is still a tiny planet when viewed through a telescope because of its distance from us. Consequently, its less than 5-arcsecond disc doesn't give up its details easily. Mars is currently a morning planet, taking part in the beautiful arrangements of planets and stars that are attractively dressing the morning sky.

At around mag. +1.6 for most of the month, Mars is an easy naked-eye target, appearing with a definite orange hue. However, it fails to reach its highest point in darkness.

MERCURY

BEST TIME TO SEE:

1 November 06:30 UT

ALTITUDE: 3° (very low)

LOCATION: Virgo

DIRECTION: East-southeast
November is not the best month for spotting little Mercury. It may be seen low in the east-southeast just before sunrise during the first week of the month, but then rapidly fades from view. Despite its brief viewing window, Mercury does have the virtue of being bright at the start of the month, hovering around the mag. -1.0 mark. It reaches superior conjunction on 17 November and becomes an evening object after that, setting with the Sun.

NOT VISIBLE THIS MONTH

SATURN

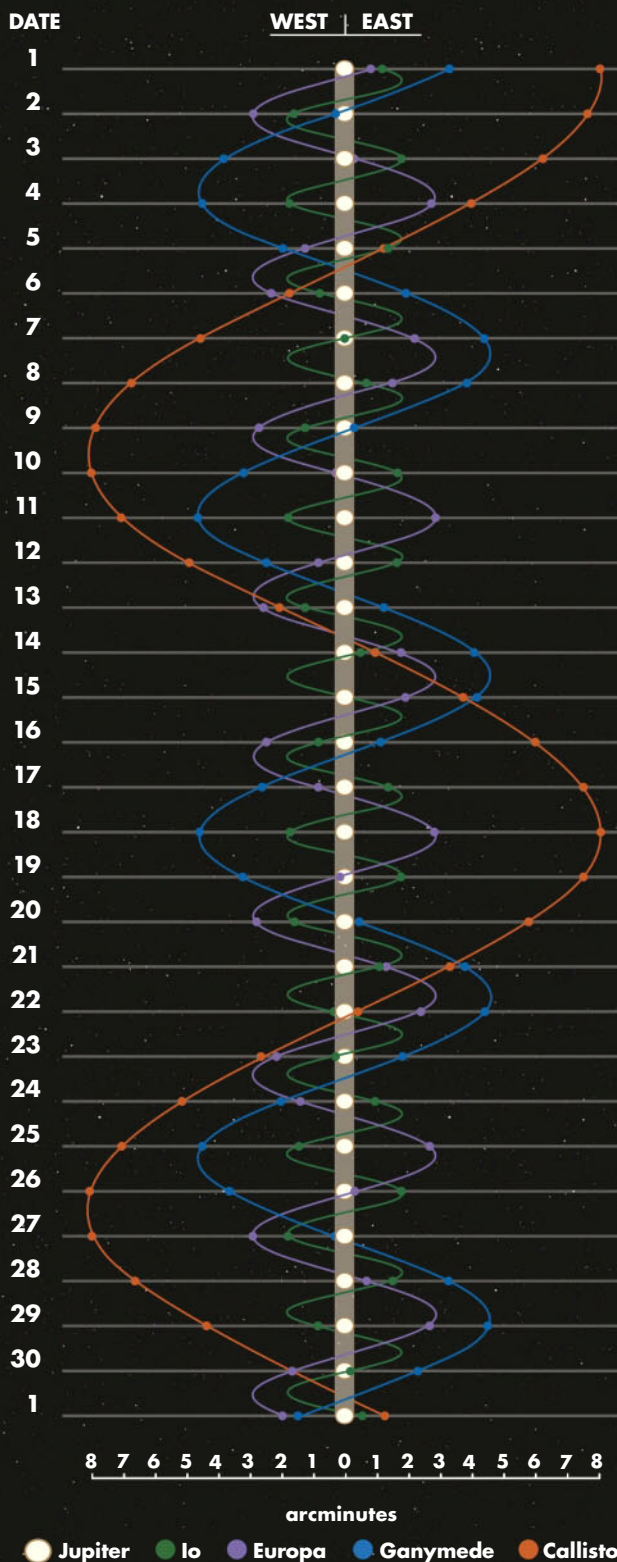
See what the planets look like through your telescope with the **field of view calculator** on our website at:

<http://www.skyatnightmagazine.com/astronomy-tools>



JUPITER'S MOONS November

Using a small scope you'll be able to spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date on the left represents 00:00 UT.



The Northern Hemisphere

KEY TO STAR CHARTS

- Arcturus* STAR NAME
- PERSEUS CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- ASTERISM
- PLANET
- QUASAR
- STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- COMPASS AND FIELD OF VIEW
- MILKY WAY

WHEN TO USE THIS CHART

1 NOVEMBER AT 00:00 UT
15 NOVEMBER AT 23:00 UT
30 NOVEMBER AT 22:00 UT

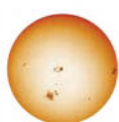
On other dates, stars will be in slightly different places due to Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

HOW TO USE THIS CHART

1. **HOLD THE CHART** so the direction you're facing is at the bottom.
2. **THE LOWER HALF** of the chart shows the sky ahead of you.
3. **THE CENTRE OF THE CHART** is the point directly over your head.



THE SUN IN NOVEMBER*



DATE	SUNRISE	SUNSET
1 Nov 2015	07:08 UT	16:38 UT
11 Nov 2015	07:27 UT	16:20 UT
21 Nov 2015	07:45 UT	16:05 UT
1 Dec 2015	08:02 UT	15:55 UT

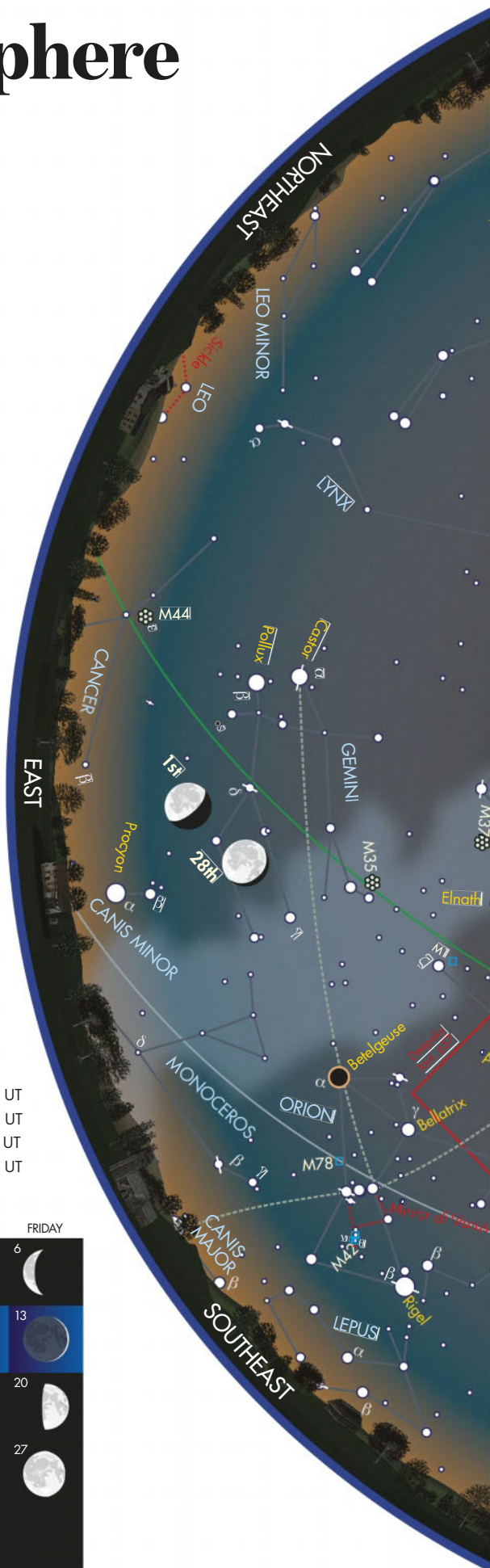
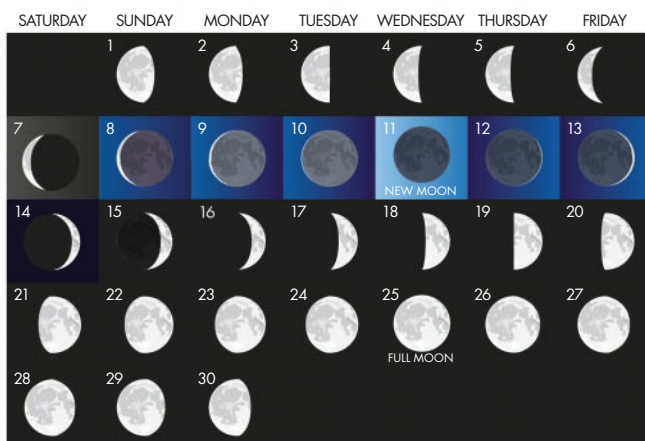
THE MOON IN NOVEMBER*

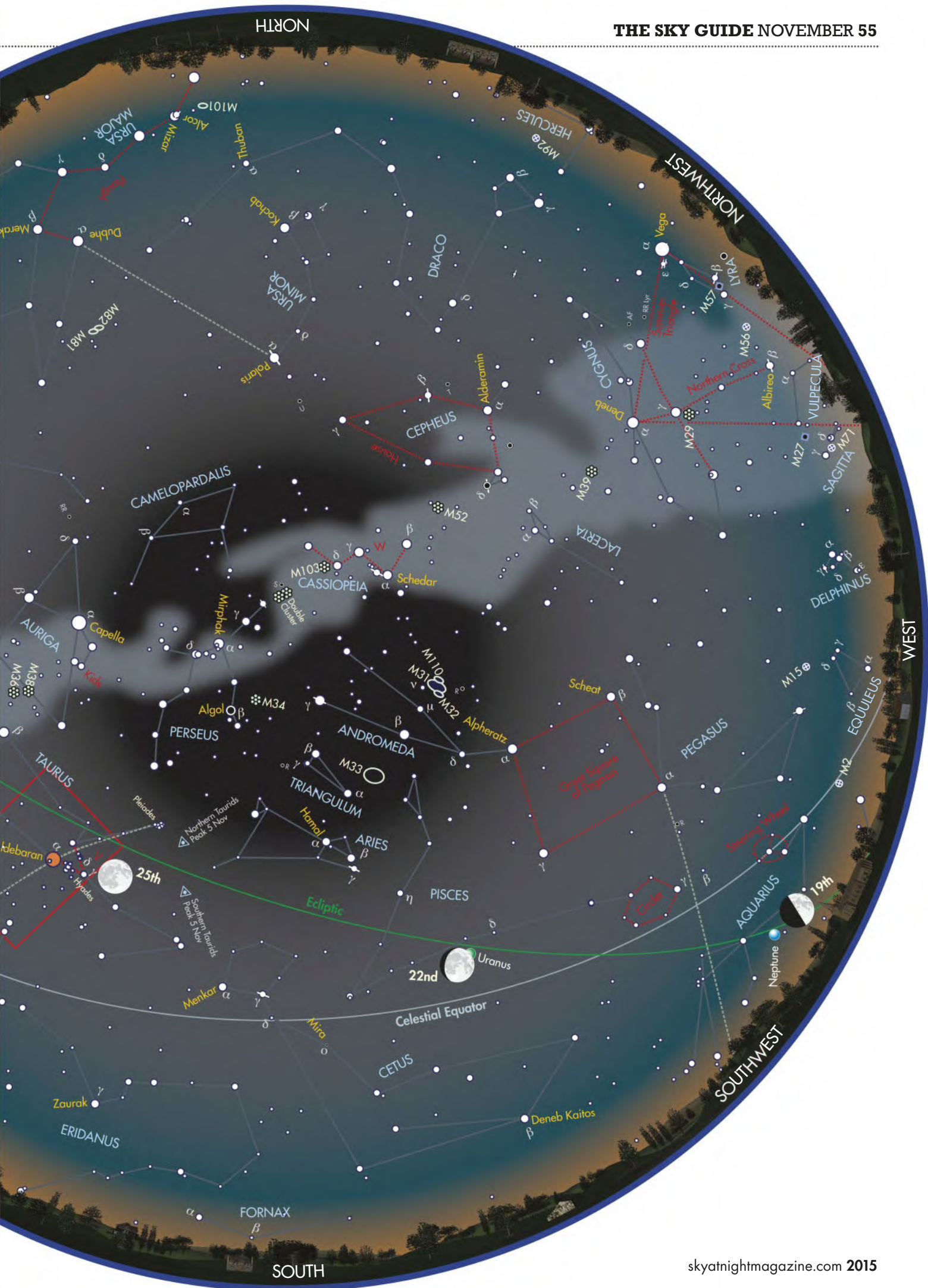


MOONRISE TIMES

1 Nov 2015, 21:13 UT	17 Nov 2015, 12:09 UT
5 Nov 2015, 00:24 UT	21 Nov 2015, 14:09 UT
9 Nov 2015, 04:39 UT	25 Nov 2015, 16:17 UT
13 Nov 2015, 08:53 UT	29 Nov 2015, 19:58 UT

*Times correct for the centre of the UK





Deep-sky tour

Use the Hyades cluster in Taurus as a starting point for some of November's finest clusters


☑ Tick the box when you've seen each one



Our third target, NGC 1662, obviously sits apart from the background sky


1

ALDEBARAN AND THE HYADES

 The familiar V-shaped Hyades open cluster is prominent this month. At 153 lightyears distant, it's the closest open cluster to Earth. The bright star Aldebaran (Alpha (α) Tauri) also appears to be in the cluster, but it is actually much closer at 65 lightyears. It has several apparent companions close by, the most obvious a mag. +11.3 star 2 arcminutes away. This turns out to be a binary star in its own right, located in the Hyades cluster – so not associated with Aldebaran. Aldebaran does however have a true companion, a mag. +13.6 star 31.6 arcseconds distant. Its closeness to the bright primary makes this a tough companion to see. ☐ **SEEN IT**


2

NGC 1647

 Imagine the line linking Aldebaran and mag. +3.5 Epsilon (ε) Tauri is a mirror. Reflect the point of the V-shaped Hyades cluster about this line to locate our next target, mag. +6.4 open cluster NGC 1647. This beautiful object is around 150 million years old and 1,800 lightyears distant. This places it behind a giant molecular cloud complex permeating much of Taurus. A 6-inch scope and low magnification will show 40 stars in a region 45 arcminutes across. Two brighter stars lie south of the cluster. The brightest is nearer at 302 lightyears, while the dimmer one is an impressive 2,400 lightyears away – much farther than the cluster. ☐ **SEEN IT**


3

NGC 1662

 We can make use of Aldebaran and Epsilon Tauri again, by extending the line they make south for about the same distance again. With a slight deviation to the west, this line points to the open cluster NGC 1662. Like NGC 1647 this is a mag. +6.4 cluster, but this time contained in an area 20 arcminutes across – so roughly half the size. NGC 1662 has an estimated age of around 420 million years. Located in the northwest region of Orion, the cluster presents two-dozen stars clearly separated from the surrounding sky. It appears quite elongated, with a beautiful condensation of cluster stars at the centre. ☐ **SEEN IT**


4

JONCKHEERE 320

 Jonckheere 320 is a mag. +11.8 planetary nebula that requires an 8-inch or larger scope to see properly. It lies 4.25° east and slightly south of NGC 1662, and about 1° northwest of the pair of stars 13 and 16 Orionis. It's an extended object formed from two lobes which, seen at magnifications lower than 50x, do a great job disguising themselves as a faint double star. If you suspect you have it centred, pile on the magnification. If you're on target, each 'star' will appear as an extended patch of light. The nebula has an associated mag. +14.4 star at its centre, which is very hard to see even with large amateur scopes. ☐ **SEEN IT**


5

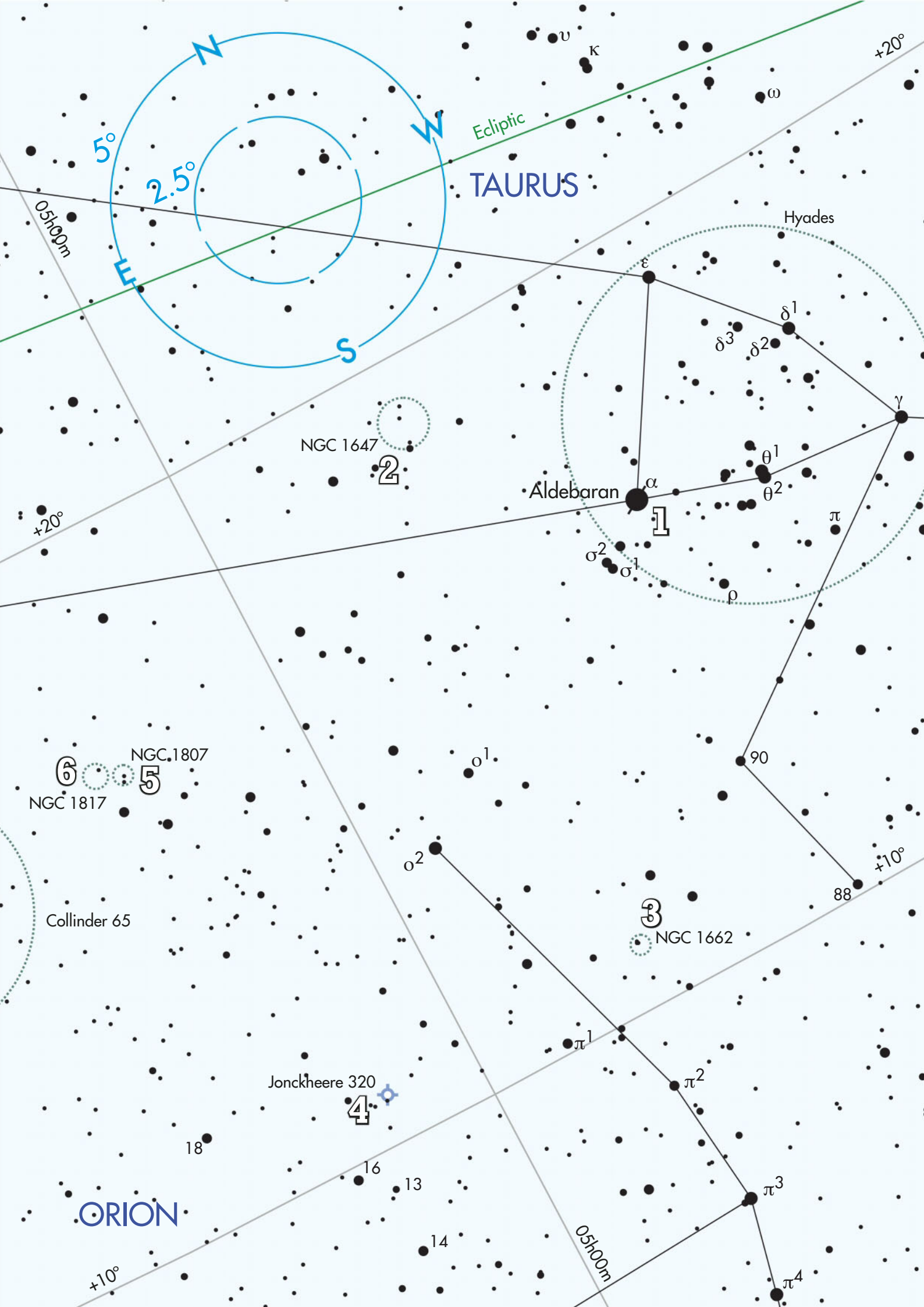
NGC 1807

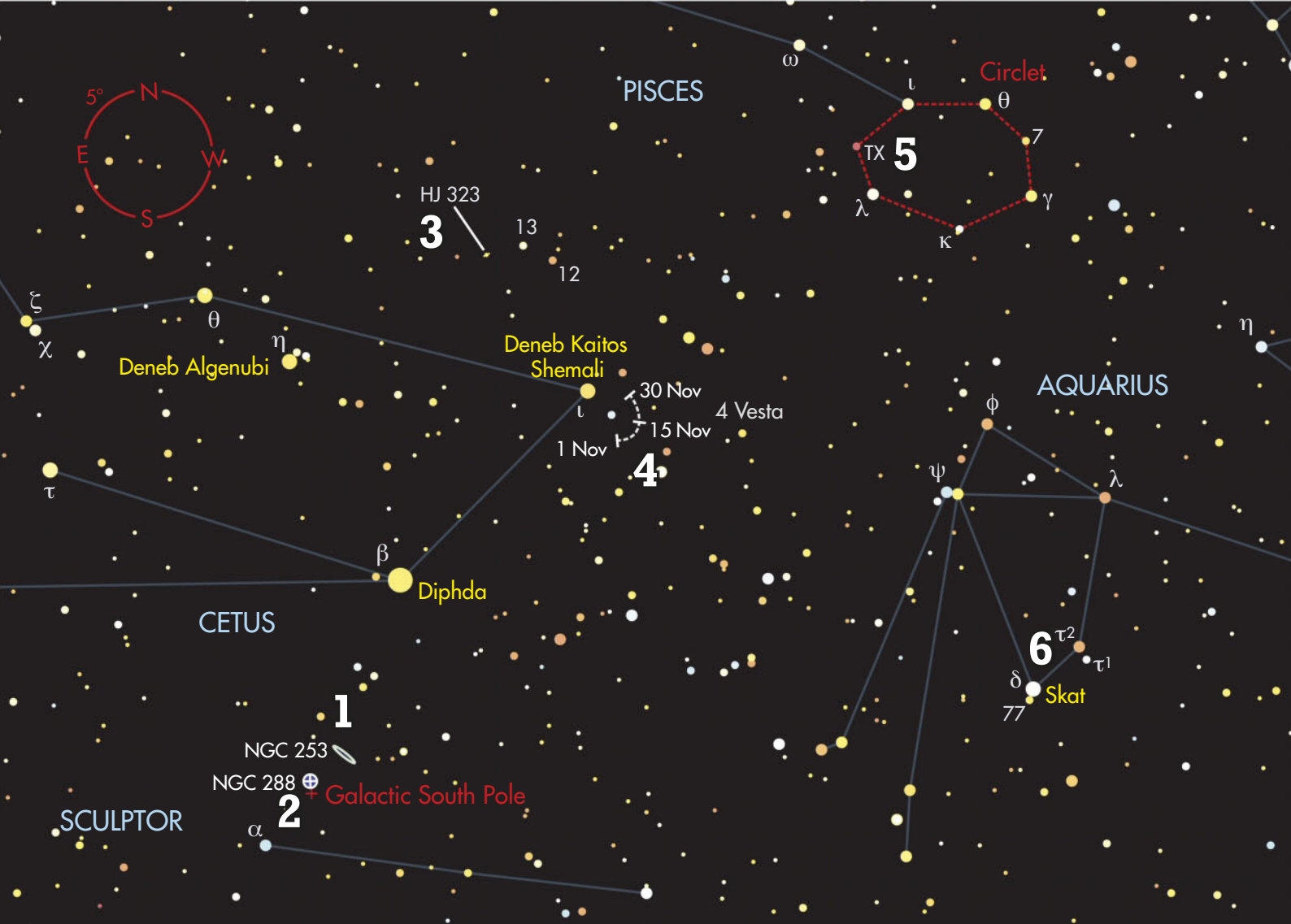
 Our fifth target is the 7th-magnitude open cluster NGC 1807. The easiest way to locate it is to draw an imaginary line from Aldebaran to the star that marks the Bull's southern horn tip, mag. +3.0 Zeta (ζ) Tauri. Locate the mid-point along this line and drop at right angles by 2.25°. Here you'll find two open clusters separated, centre-to-centre, by 22 arcminutes; a bit like a faint version of the Double Cluster in Perseus. The western cluster is T-shaped NGC 1807, and at mag. +7.0 it is also the brightest of the pair. Here you'll see about a dozen stars of between mag. +8.5 and +10.5 scattered across an area 12 arcminutes across. Its neighbour is our final stop of this month's tour. ☐ **SEEN IT**

6

NGC 1817

 Our last target is next door to NGC 1807. NGC 1817 is a mag. +7.7 cluster which, through a small scope, appears as a line of stars running north-south with a patch of haze to the east. This is formed from closely packed 11th-magnitude stars and best seen using averted vision. A 10-inch scope will resolve the haze into around 70 individual stars. These occupy an area roughly 0.25° across. It is interesting having NGC 1807 so close, as it's possible to compare both clusters. Despite having a fainter magnitude rating, NGC 1817 turns out to be the richest of the pair. ☐ **SEEN IT**





Binocular tour

Look out for the goddess of the hearth, a ruby droplet and some deceptive doubles

With

Stephen Tonkin

☒ Tick the box when you've seen each one

1 THE SILVER COIN GALAXY

10x 50 Just over 4° to the south of mag. +2.0 Diphda (Beta (β) Ceti), you will find a right-angled triangle of 5th-magnitude stars. The bright Silver Coin Galaxy, NGC 253, appears as an elongated glow nearly 3° to the south of this triangle. It has a major axis of about half the diameter of the Moon, and you should notice that it has a brighter core. Despite its low declination, this is a relatively easy object for small binoculars as long as you have a decent southern horizon. This is the best time of year to observe it from Britain. ☐ **SEEN IT**

2 NGC 288

15x 70 Mag. +8.1 globular NGC 288, which lies slightly less than 2° to the southeast of NGC 253 in the direction of mag. +4.3 Alpha (α) Sculptoris, is another easy object as long as you have a good southern horizon. In a pair of 15x70 binoculars, it appears as a dim circular glow which, with averted vision, seems to grow to about half the diameter of NGC 253.

NGC 288 is a good marker for the Milky Way's south pole, which lies 36 arcminutes away in the direction of a 7th-magnitude star 2° to the south-southwest. ☐ **SEEN IT**

3 HJ 323

10x 50 Imagine a line joining mag. +3.4 Deneb Algenubi and mag. +3.5 Deneb Kaitos Shemali (Eta (η) and Iota (ι) Ceti). Around 5° north is a row of six 6th- and 7th-magnitude stars that is nearly 6° long. The brightest in the row is 13 Ceti, and the star that is 1.5° to the east-southeast of this is HJ 323, a double star discovered by Sir John Herschel. The brighter component, which shines at mag. +5.9, is nearly 10 times brighter than the white secondary (mag. +8.4), which lies 63 arcseconds away in the direction of 13 Ceti. ☐ **SEEN IT**

4 VESTA

10x 50 The asteroid Vesta spends November moving along a 2.5° arc centred between Deneb Kaitos Shemali and mag. +4.9 star 3 Ceti,

as its apparent motion changes from retrograde to prograde. Currently at mag. +7.2, Vesta is an easy binocular object. It was discovered by Heinrich Olbers in 1807 but, as he had already named an asteroid (Pallas), he invited Carl Friedrich Gauss, whose calculations confirmed the orbits of the first asteroids, to name his new discovery; Gauss named it for the Roman goddess of the hearth. ☐ **SEEN IT**

5 TX PISCUM

10x 50 Locate the southern circlet of Pisces and here, on its eastern side, we find one of the reddest stars in the night sky, the slightly variable (mag. +4.9 to +5.2) TX Piscium. You should also notice that, as you gaze at this ruby droplet, it seems to be brighter than when you first located it. This phenomenon, called the 'Purkinje effect', is more pronounced in larger apertures and leads to a systematic overestimation of the magnitude of red stars unless you only take quick glances at it. ☐ **SEEN IT**

6 REVERSE DOUBLES

10x 50 Our final target is actually a pair of wide double stars; the first mag. +3.3 Skat (Delta (δ) Aquarii) and mag. +5.5 77 Aquarii, separated by 27 arcminutes; the second mag. +4.0 Tau² (τ²) and mag. 5.7 Tau¹ (τ¹) Aquarii, separated by 39 arcminutes. The redder star is the brighter of the two in the second pair, the reverse of the first. The Purkinje effect can produce a brightening of about 0.5 magnitudes – try using it to reverse the brightnesses and make Tau² appear brighter than Skat. ☐ **SEEN IT**

Moonwatch

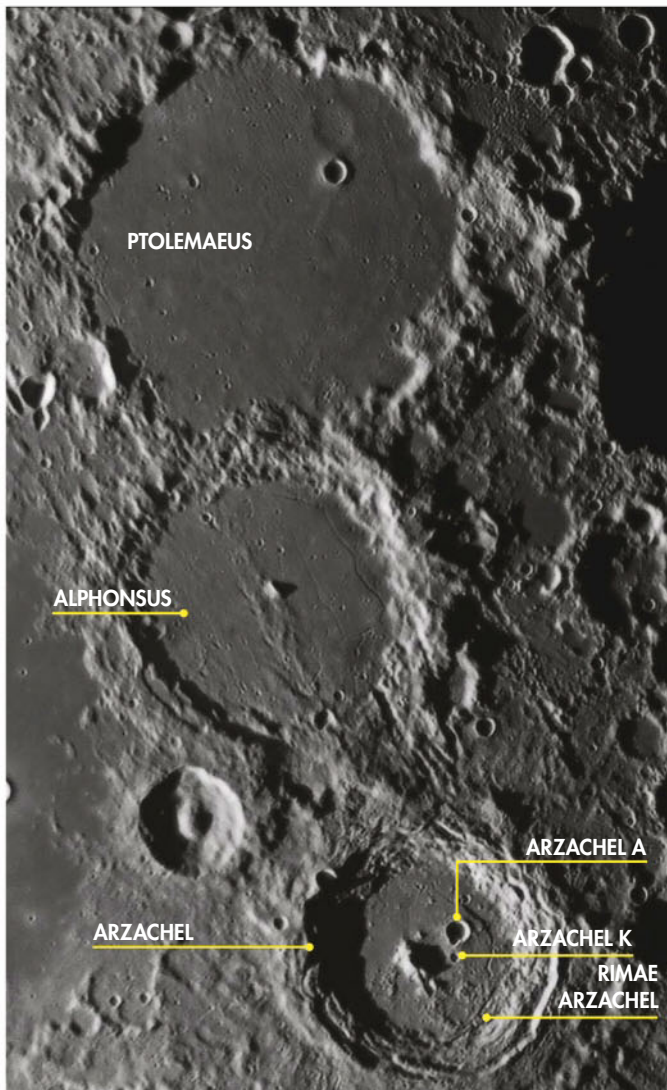
Crater Arzachel

ARZACHEL IS THE southernmost crater in a prominent north-south trio located in the southern-central region of the Moon. Immediately north of it lies 118km Alphonsus, and to the north of that, the massive 154km walled plain of Ptolemaeus. Arzachel is the youngest of the three, a fact emphasised by its sharper and more prominent features.

Its rim is highly terraced, forming a transition boundary between the rough highlands that surround it and the

relatively flat crater floor within. The rim towers above the floor to a height of around 3.6km and it is fascinating to spend time delving in and out of the terraces when the terminator isn't too far away. There are a number of similarities between the appearance of Arzachel and the dramatic 93km ray crater Copernicus.

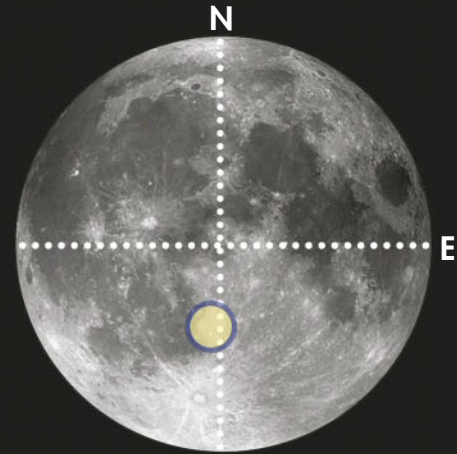
Both are of similar size and both have terraced walls surrounding a relatively flat floor with a central mountain complex. Copernicus gains



Arzachel is the southernmost of this famous trio of adjacent craters – look when the terminator is close to catch its sharp features

STATISTICS

TYPE: Crater
SIZE: 98km
AGE: 3.8-3.85 billion years
LOCATION: Latitude 18.3°S, longitude 1.9°W
BEST TIME TO OBSERVE: Six days after full Moon or first quarter (3-4 November and 19 November)
MINIMUM EQUIPMENT: 2-inch refractor



“There are a number of similarities between Arzachel and Copernicus”

more attention partly because it's younger and better defined, but mostly because it has been formed in the dark lava of the Mare Insularum. Copernicus's ejecta rays draw your eye to the crater at the centre.

Arzachel is older and appears more eroded. But most importantly of all, the highly cratered highland surroundings provide camouflage, reducing its visual impact. In addition, any ejecta rays from Arzachel have long since darkened and faded away. So despite similarities between the main craters, Copernicus and Arzachel have very different visual calling cards.

A prominent, 19km long central mountain complex sits slightly offset to the west of Arzachel's centre. This too towers above the surrounding floor to an estimated height of around 2km. The prominent 10km crater Arzachel A is an easy target on the floor of Arzachel itself, located 20km to the east of the central mountain. Look carefully and it should be obvious that an even smaller craterlet, 4km across, sits right on the southern lip of Arzachel A, tricky to spot because it blends in with the larger crater. Another 4km craterlet, Arzachel K, lies 5km to the south.

Cracks run in the floor of the main crater. Known as Rimae Arzachel, these run around Arzachel A, passing between it and the main crater rim to the east. Several tributaries 'flow' off the main rille to the north and south. Those to the north have a greater spread and for those with larger instruments or high-resolution imaging kit, an interesting observation is to try and see the narrow crack that runs right back to the central mountain. An 8-inch telescope is required to see the Rimae Arzachel.

The Ptolemaeus-Alphonsus-Arzachel trio is one of the most recognisable lines of craters on the Moon's Earth-facing side. The progression of increasing diameters, along with greater age as you head north, really makes them very noteworthy. This is especially true when the terminator is close by.

Arzachel's sharp features strike distinct and dramatic shadows at such times while the others tend to be more subtle. The huge initially flat floor of Ptolemaeus at the north of the trio is especially interesting as a low Sun angle reveals the lumps and bumps of craters swallowed up beneath the lava that creates it's massive floor.

Astrophotography

Photographing the Pleiades open cluster



RECOMMENDED EQUIPMENT

DSLR or CCD camera, telescope, driven equatorial mount



Though stunning visually, only images can reveal the Pleiades' dimmer members and nebosity

THE PLEIADES IS surely one of the best naked-eye objects in the autumn sky, if not the entire sky. It's a beautiful cluster of young blue stars that tantalise your eyes on a cold dark November evening.

Visually appealing, the cluster becomes even more alluring in photographs. Open clusters tend to be a bit more forgiving of light pollution because stars are basically points of light. However, in the case of the Pleiades, there's nebosity to be had too, and to capture that well you'll need a clear, crisp and dark sky.

The nebula that permeates the cluster comes from a collision between the cluster stars and possibly two galactic dust clouds. The clouds scatter and reflect the light from the stars, creating a reflection nebula. Unlike its emission nebula counterpart, a reflection nebula tends to look blue in long-exposure shots.

The cluster has approximately 1,000 members. The brightest of these are named after seven daughters of Atlas and Pleione in Greek mythology, plus Atlas and Pleione themselves. The brightest

stars are easy to see with the naked eye and despite the cluster's common name, the Seven Sisters, there are more than seven stars that can be seen. Stick a camera on the cluster and many of the dimmer members become visible.

Capturing the delicate nature of the reflection nebula that permeates the cluster stars is tricky, requiring a deft hand at imaging processing to get it just right. A short exposure on low ISO will typically show the brighter stars with none (or just a hint) of the nebosity. This is a good way to record what the cluster looks like visually, but nonetheless a close-up at low ISO can be a little unrewarding as the stars of the Pleiades are actually quite well separated in the sky. The longest axis formed by the brightest stars is around 1° so two full Moons would fit across the length of the cluster. Using a focal length of around 500mm, ISO 800 and a telescope in the f/5-f/9 range should start to produce the

nebosity around the brighter stars with an exposure of 60 seconds.

With modern cameras and less than perfect equatorial mounts, it's tempting to up the ISO to bring out more detail but, apart from increased noise, this will produce a flatter tonal range making the cluster look washed out. Some of the colourful stars that appear in front and behind the cluster also start to lose their distinctive colour contrast.

ISO 400-800 is about the right range, with the lower value being preferred if you have accurate tracking. A focal length of 500mm gives a good amount of space around the main cluster with a non full frame DSLR. If your sky is light polluted, obtaining a good shot of the nebosity requires a balancing act in terms of exposure.

A well-aligned equatorial mount is also essential for the best results, and autoguiding can be a massive help in keeping those delicate cluster stars nice and round. Even though not to everyone's taste, diffraction spikes formed from the spider of a reflector can add a certain something to the Pleiades.

If you use a refractor or standard camera lens, one method of generating the spikes naturally is to create a cardboard collar that just fits around the end of the lens. Two pieces of cotton crossed at right angles fitted to the collar will then be enough to create the spike effect.

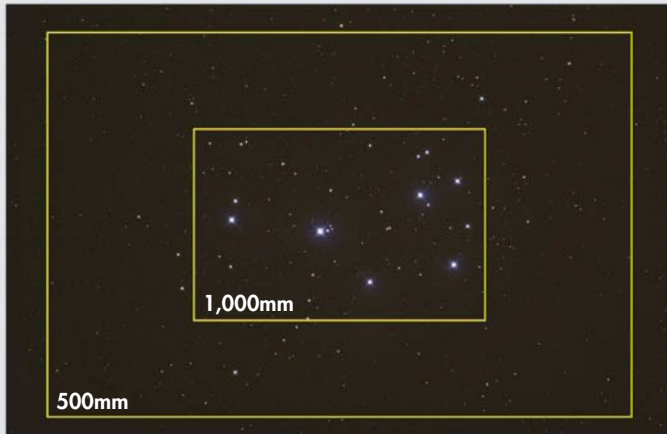
KEY TECHNIQUE

AVOID THE PITFALLS

One common mistake when imaging the Pleiades is to forget composition. If the frame is too small, the cluster will look constrained and the image won't sit easily to the eye. Extra space around the cluster and aligning so the perceived axis runs approximately parallel with the long frame axis works well. Also consider the colour: though often described as blue, the nebula is fairly subtle, being more grey-blue than pure blue. The final processing steps should take this into account to produce a shot that really does the sisters justice.

✉ Send your image to: hotshots@skyatnightmagazine.com

STEP-BY-STEP GUIDE



STEP 1 It's important that the Pleiades have enough room to 'breathe' in the shot. A non-full frame DSLR coupled to a 1,000mm focal length telescope gives a field 1° and 15 arcminutes by 51 arcminutes. Although the main cluster would fit in the frame, it's tight. Shorter focal lengths will add more space around the edge, relaxing the view.



STEP 2 Centre the cluster and rotate the camera so the longer dimension of the main pattern aligns with the long axis of the camera frame. Alternatively, rotating the camera by 45° clockwise works well too. The main stars are bright enough that they should show up in a camera's live view window. Focus as accurately as possible.



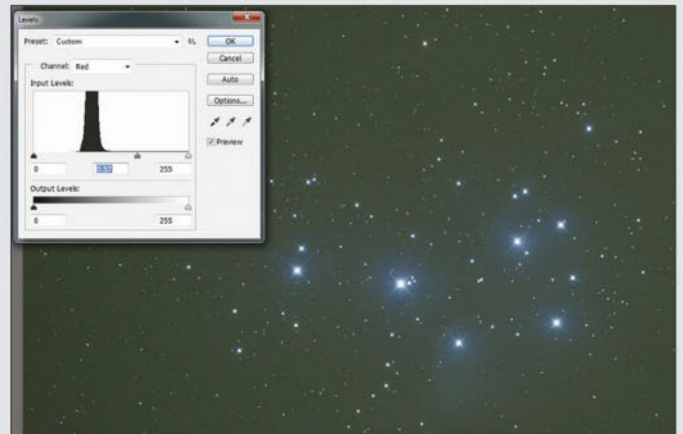
STEP 3 Final settings should be adjusted according to setup and sky conditions, but to begin set the camera's ISO to 800. If using a normal camera lens, set to lowest f/stop then close by a stop or two to avoid distortions. With the tracking drive turned on, switch the camera to bulb mode and use a shutter release cable to take a 60-second exposure.



STEP 4 If the result shows no trailing, attempt longer exposures adding an extra 30 seconds each time. As soon as trailing appears, revert to the previous setting. Also check that any light pollution present is not overexposing the result. Set the camera to save in the RAW format (or RAW plus large JPG), and take at least 25 images (light frames).



STEP 5 Cover the lens and take at least 16 dark frames using the same settings. An evenly illuminated white cloth stretched over the lens can be used to take flats; adjust the exposure so the histogram peaks around 60-70 per cent saturation and take at least 16 of these too. Your lights, darks and flats can be combined using a program such as DeepSkyStacker.



STEP 6 If light pollution creates an orange cast, adjust the image's levels in an editor. Nudge the red mid-point towards the black point until a slight green tint appears. Nudge the green mid-point to correct. Adjust blue similarly if required. The nebula should appear more grey-blue than blue. If yours looks intensely blue, desaturate the blue channel slightly.

A composite image featuring the Rosetta spacecraft in the upper left, with its long boom and solar panels extending across the top. Below the spacecraft is the large, irregular, and heavily cratered nucleus of comet 67P/Churyumov-Gerasimenko. The background is a deep black space filled with distant stars.

Rosetta

THE JOURNEY SO FAR

Will Gater looks back
at the last year of ESA's
mission to comet 67P/
Churyumov-Gerasimenko



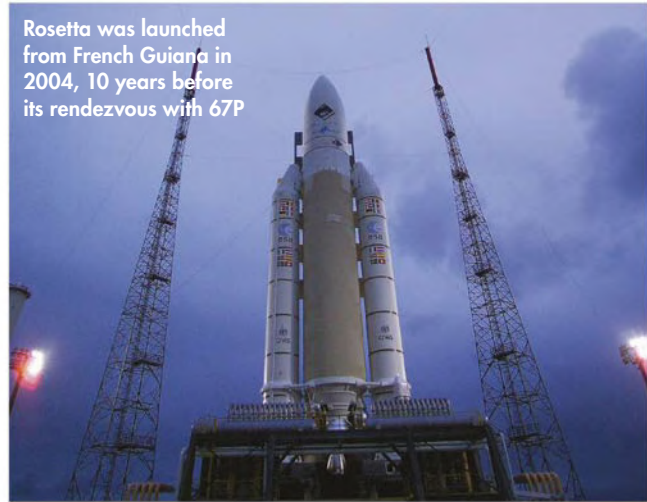
ABOUT THE WRITER

Will Gater (@willgater) is
an astronomer and journalist.
He is the author of several books
and presents live astronomy
shows for Slooh.

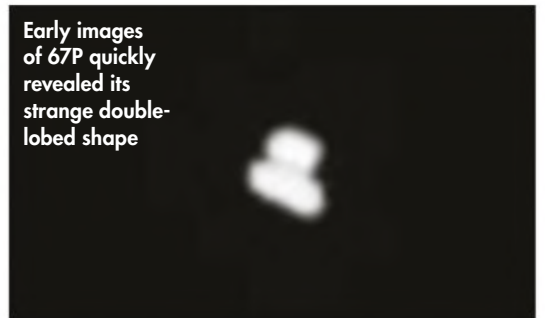
67P/Churyumov-Gerasimenko up close; its unusual, unexpected shape led to it being called the 'rubber duck' comet



Rosetta was launched from French Guiana in 2004, 10 years before its rendezvous with 67P



Early images of 67P quickly revealed its strange double-lobed shape

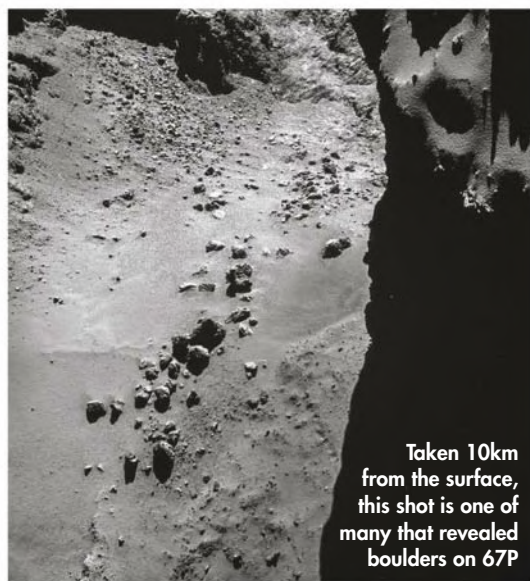


Surprise and serendipity have always been one of the great joys of exploration – precious moments of insight or understanding that reveal the beauty, and perhaps even the eternal mystery, of the Universe we inhabit. For the scientists working on ESA's Rosetta mission, this past year has brought more than its fair share of unexpected excitement. One need only look at the images the spacecraft returned early last summer to see this extraordinary drama writ large.

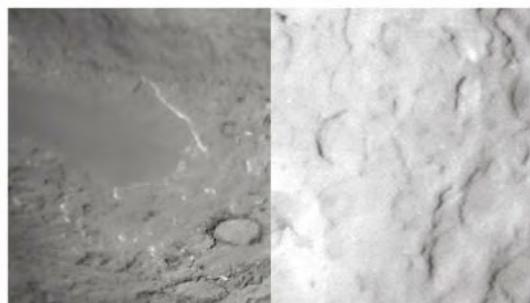
Rosetta was launched in March 2004. Its aim was to rendezvous with and eventually orbit the nucleus of a comet, a periodic visitor to the inner Solar System known as 67P/Churyumov-Gerasimenko. Astronomers had expected the 4km-wide lump of ice and dust to look a little bit like a potato, with a few large bumps sticking out here and there. But as the probe neared its target in July 2014, the comet produced a major surprise: images from Rosetta's cameras showed that rather than being a single and broadly-round body, 67P was comprised of two huge interconnected 'lobes'. "It's just nuts," says the mission's project scientist Matt Taylor, reflecting on the discovery of the unusual shape.

It was about to get weirder

By August the views from the spacecraft were even more spectacular. Dramatic monochrome images taken by the spacecraft's navigation camera on arrival at the comet showed rough outcrops and towering cliffs covering its craggy body, while high-resolution pictures from Rosetta's OSIRIS instrument revealed enormous boulders strewn across the surface. Where the two lobes met, the ▶



Taken 10km from the surface, this shot is one of many that revealed boulders on 67P



▲ Cliffs similar to those on Tempel-1 (left) and pits like those on Wild-2 (right) have both been seen on 67P

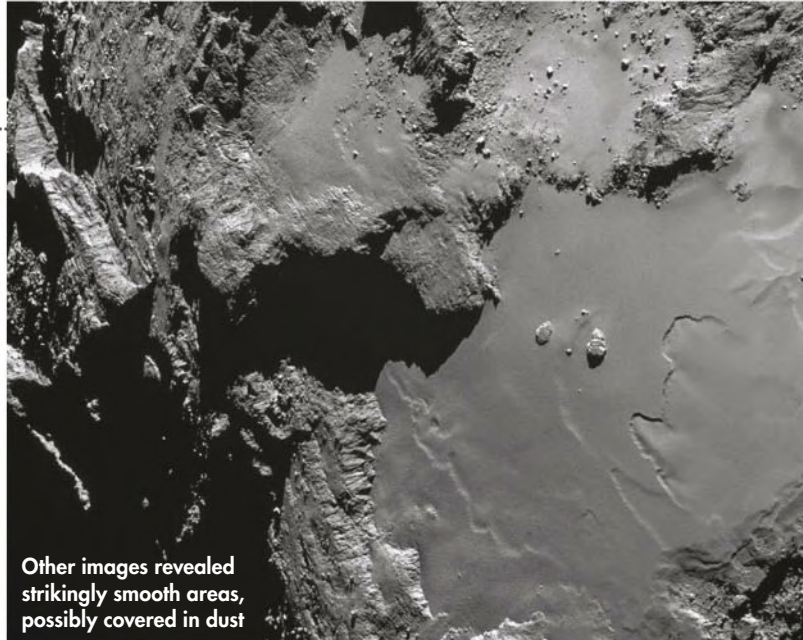
► probe's cameras even revealed an unusual, smooth region flanked by steep escarpments. "I heard a number of comet experts noting the similarities to other cometary bodies that we have observed," says Taylor. "We have aspects of all other comets rolled into one."

That's a view echoed by Carsten Guettler, who works with Rosetta's OSIRIS instrument. "Comet Wild-2 showed the pits that we are also seeing now; Tempel-1 showed cliffs, which manifest as terraces on 67P. There are smooth, dust-covered regions that were expected from dust fall," he says.

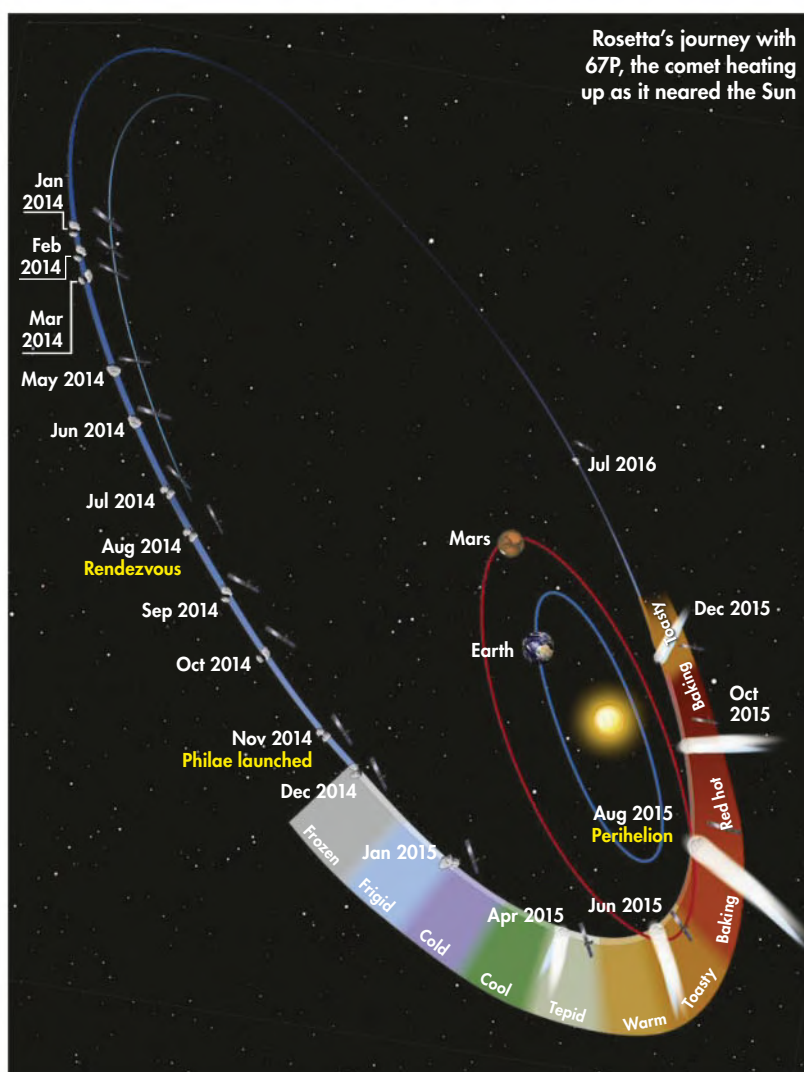
"On the other hand, we expected to see at least some impact craters but now we don't. Did the comet not experience as many collisions as we expected or were they all washed out from the activity? We have many ideas on how the activity shapes the surface, how it is connected to cliffs, fractures, pits and flat lands. The one theory to combine all these ideas while being consistent with all that we see and know will take a lot of time."

In for the long haul

Thankfully time is something that the Rosetta team has had a great deal of. Rather than being a fleeting flyby mission, the spacecraft has stayed close to 67P since its arrival. That's allowed the scientists to not only scrutinise the surface in detail but also watch how the comet changes and evolves as it nears the Sun.



Other images revealed strikingly smooth areas, possibly covered in dust



This pioneering flight plan comes with its own challenges though.

"What we are doing hasn't been done before," explains Taylor. "We predicted how things would be, but, as usual, things don't always go to plan. We had expected it to be dusty, but the dust environment is much more complex than we expected. As such we are unable to navigate very close to the comet as the star trackers, necessary for accurate pointing, get confused when there is a lot of dust around." ►

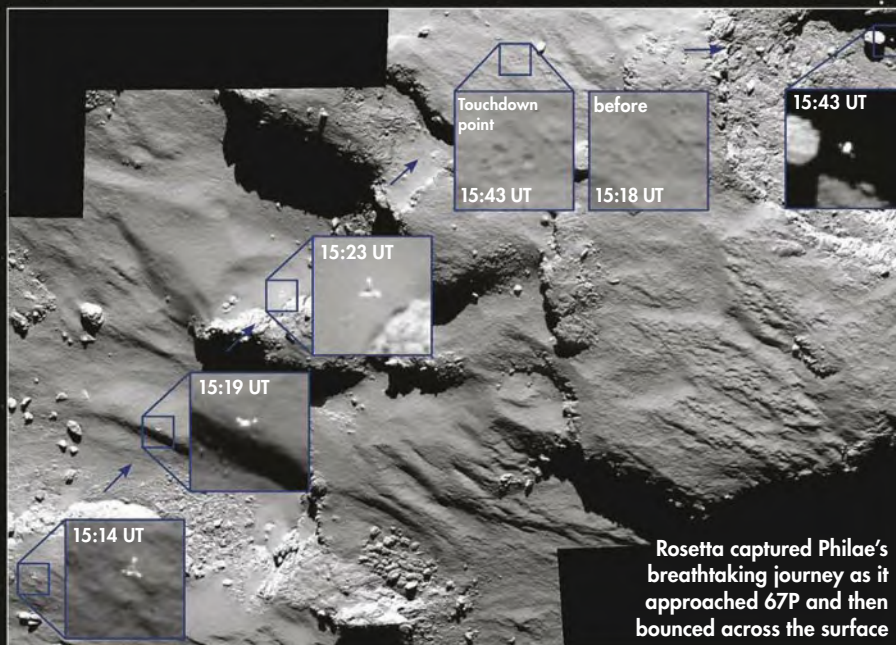
THE FLIGHT OF PHILAE

With no way to steer, landing on an active comet proved tricky

On 12 November last year the Philae lander was released from Rosetta and sent drifting down to the comet below. With no means to steer or manoeuvre the probe, though, all the teams could do was wait, hoping that the trajectory they'd sent it on would take it safely to the landing site. After hours of waiting the signal came: Philae had reached the surface. But all had not gone precisely as it should have.

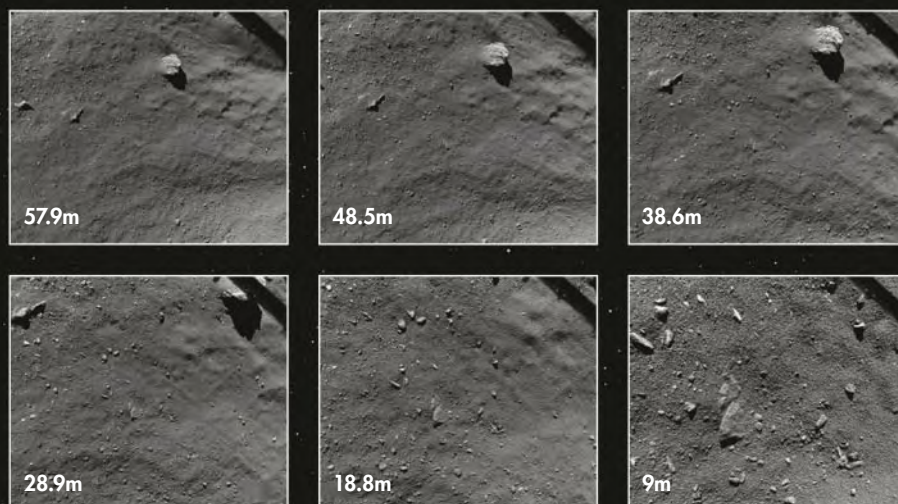
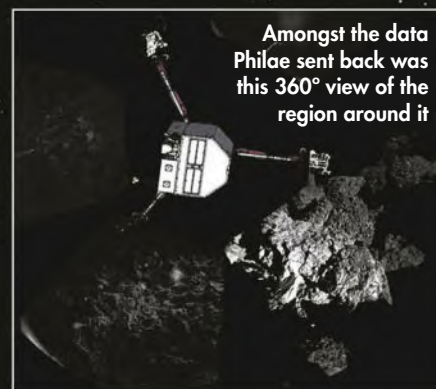
Harpoons were supposed to fire and anchor the lander to 67P, but they don't appear to have worked, and Philae bounced right off the comet. It then 'flew' over the surface for a while before touching down and bouncing off once again. The probe only came to a rest after its third 'landing'. "At the moment the details of the lander hopping across the surface are still not fully understood," says Hermann Böhnhardt, one of the lead scientists on the Philae mission.

Despite its little unplanned jaunt, Philae returned extraordinary images during its descent and from at its final landing site. One of Philae's instruments measured changes in temperature from -145°C to -180°C at its landing site while another, the lander's onboard hammer, sent back data that suggested that the surface of its resting place was made of hard ice and dust covered in a coating of dusty material just a few centimetres deep. Other instruments even uncovered the presence of a number of organic (containing carbon) compounds, which will no doubt be of interest to astrobiologists. However there are limits to what it could do, says Philae scientist Aurélie Moussi. "The soil seemed to be too far from the lander to retrieve a solid sample from the surface to be analysed onboard," she says.

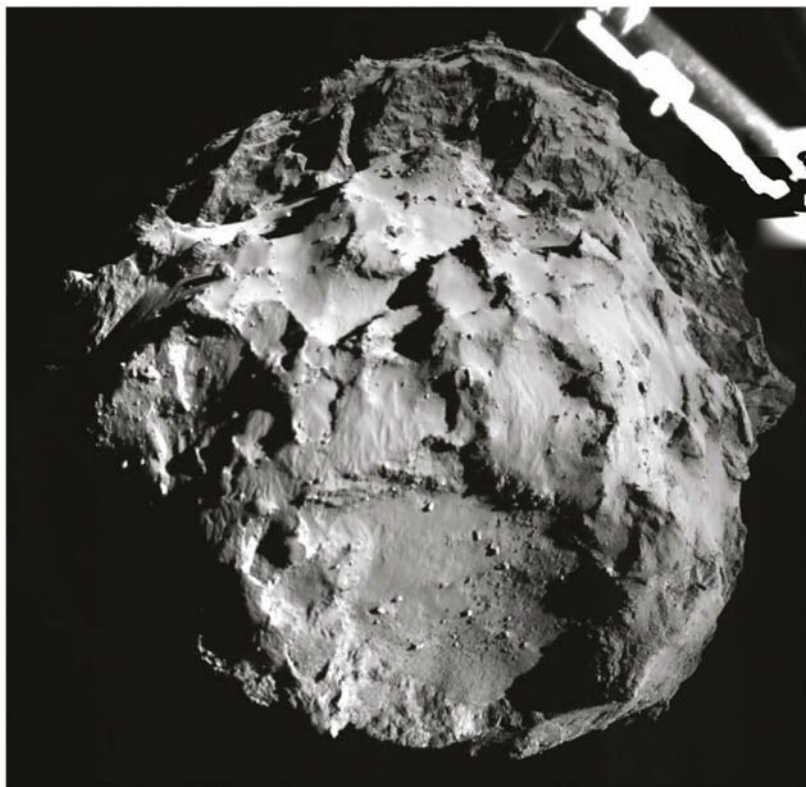


Philae is thought to have ended up almost on its side, making the initial communication, and charging of the probe's solar panels, tricky. Eventually contact was lost, but in June and July this year the probe got back in touch, albeit briefly. "The short contacts have allowed [us] to collect so-called house keeping data which allow [us] to assess the lander subsystem status," says Böhnhardt. "No science data were received."

It's not known if Philae will communicate again, but its story certainly isn't over. In the coming months the Rosetta team hope to image it sitting on the comet, finally pinning down its exact location on the surface.



▲ Philae continued taking images during its slow descent to the comet, returning these shots



► Despite these difficulties, Rosetta's suite of instruments has been hard at work analysing the comet and the material it's been giving off. Data from the spacecraft has enabled researchers to determine the ratio of hydrogen to deuterium in 67P and even uncover the signature of molecular nitrogen around the comet. "These measurements indicate the comet is very old and has spent a long time in the outer parts of the Solar System," says Taylor. "This puts all other measurements into context – they are all of a very primordial body, made at the time of Solar System formation and not perturbed much since."

While Rosetta provides valuable observations as it buzzes around the comet, the mission design also incorporated a plan to get a close-up view of 67P. In November 2014 the orbiter deployed a small lander, named Philae, resulting in one of the most thrilling spacecraft descents ever seen in planetary exploration. And although the initial landing didn't quite go to plan (see 'The flight of Philae', page 65), the probe did return unprecedented images and data from the surface of the comet.

Back in orbit, Rosetta would try to help pin down Philae's location, but as the weeks went by its instruments and cameras were also witnessing something incredible happening on the comet; 67P was becoming more and more active as it approached perihelion, the closest point in its orbit to the Sun.

Jean-Baptiste Vincent from the Max Planck Institute for Solar System Research had been studying the activity of 67P long before Rosetta arrived at the comet. "At that time I was working more on large scale coma structures observable from Earth," he says – the 'coma' being the haze

▲ Philae's leg can be seen in the top right of this image of its approach to 67P

▼ Overexposed images like this reveal the numerous jets blowing from the comet



▲ Even by the end of April 2014, 67P/Churyumov-Gerasimenko was displaying a prominent coma

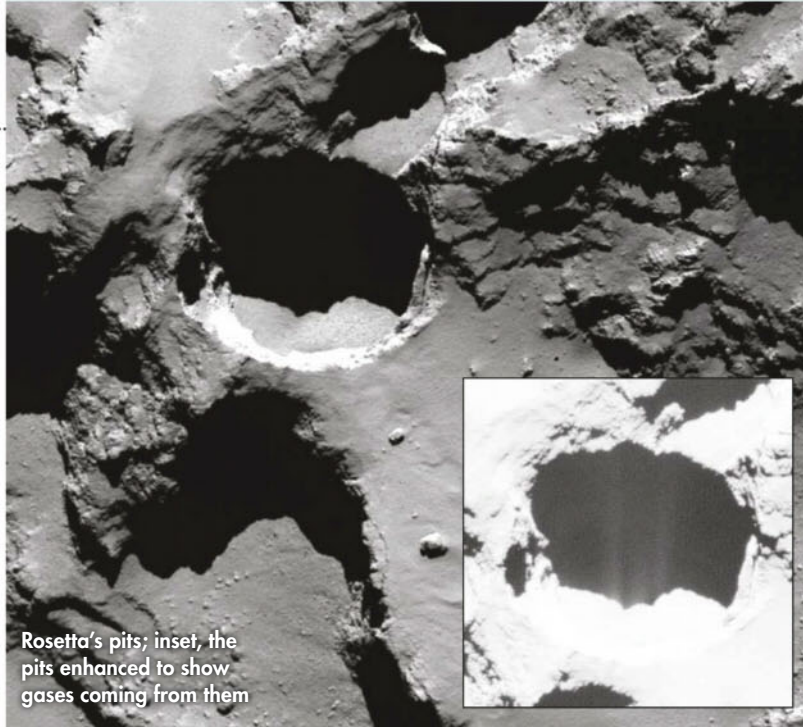
of dust and gas enveloping the comet's central nucleus. As Rosetta closed in on the comet, Vincent and his colleagues working with the spacecraft's OSIRIS instrument began to see activity increasing at their far-off destination.

Mystery outbursts

"The first sign was that the comet was not a single point light source anymore like in our early images, from March 2014, but that it had developed a coma," recalls Vincent. "This was expected but still nice to see. Much more surprising was the big outburst we observed at the end of April 2014, with the sudden release of about 10 tonnes of cometary material. We still do not know what triggered this event."

With Rosetta flying around 67P, OSIRIS's cameras have been regularly keeping watch for changes on the comet. "Our modelling predicted that activity would arise mainly from high northern





Rosetta's pits; inset, the pits enhanced to show gases coming from them

latitudes on the nucleus around the time Rosetta reached the comet," says Vincent. "While our predictions were correct, we quickly realised that the large scale jets are really made of many much smaller structures."

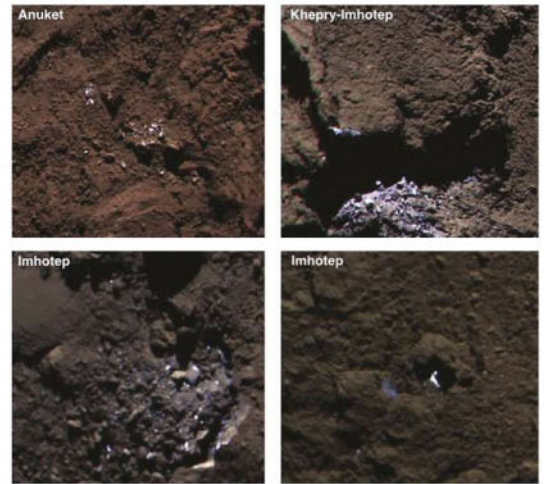
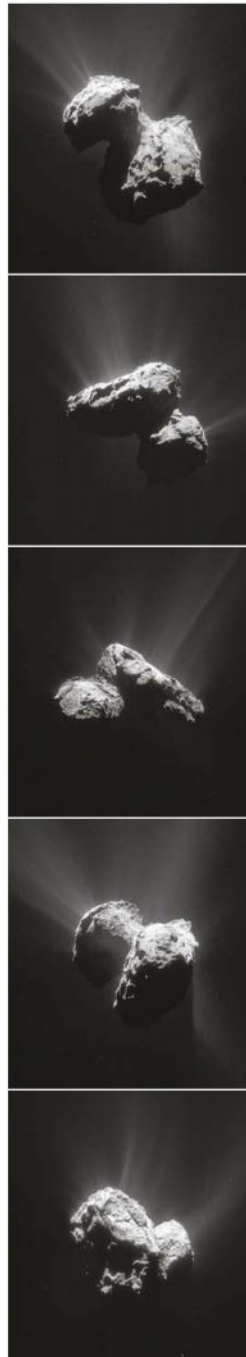
Perhaps most excitingly, several of those smaller structures appeared to be associated with huge 'pits' in the surface of the comet. "We noticed the pits immediately upon arrival but it took us a few weeks to realise that they were active," explains Vincent. By carefully processing high-resolution images of these cavernous depressions, Vincent and his colleagues have been able to reveal faint jets flowing from some of them at a few metres per second. "Our images have a very high range. They contain more shades of grey than our screens can display," he says. "This means that shadowed areas or dark spots in our images still contain a lot of signal. By enhancing the brightness and contrast we can peek through the shadows and retrieve this additional information."

As 67P neared the Sun its activity increased dramatically: more and more gas and dust was being driven off the surface each day by the warmth of our star. Around the time of perihelion in August 2015, Rosetta's cameras caught several spectacular cometary jets flaring from the icy nucleus. "On 29 July we saw a very strong outburst in one image," says Guettler. "Fifteen minutes before there was nothing." Guettler says now the aim is to explore exactly how these remarkable jets form. "We have dedicated OSIRIS observations that are monitoring presumed active regions – regions where we have seen outbursts before. We want to see a jet being born and dying," he says.

The allure of ice

It's not just the jet activity that's fascinated the Rosetta team either. The spacecraft's cameras have also spotted the distinctive glisten of ice on the nucleus of the comet. "We did not see ice from the beginning. It was covered with a dust mantle, which was isolating the ice from direct Sun exposure and also making it invisible to our cameras," explains

▼ Rosetta will stay with 67P until September 2016, so we can expect plenty more images like these



▲ Multiple bright patches of ice have been seen, and evidence so far points to them being water-ice

Guettler. "We always knew it must be there and when the comet slowly heated up while it was approaching the Sun, the ice evaporated and lifted the dust blanket. So wherever we see ice these are very active areas."

With all this activity at 67P, the Rosetta spacecraft is getting an unprecedented view of the evolution of a comet and the processes at work on its surface. But understanding the context of this activity is vital to the mission too. It's for this reason that hundreds of astronomers around the world, using ground and space-based telescopes, have also been studying Rosetta's target.

"There's a lot of chemistry and physics going on in a comet's coma as the gas and dust interact with the ultraviolet radiation from the Sun, so understanding the large scale at the same time as we get in-situ measurements from Rosetta is key to better understanding these processes," says Colin Snodgrass, who is coordinating the observing campaign. "Ground-based data also allows direct comparison with other comets, as we have similar observations of them. In this way it helps us use Rosetta results to interpret what we see in observations of comets more generally."

Amateur astronomers have played a part in the campaign too. "They have been collecting images of the comet, which allow us to follow its large scale structure and total brightness," says Snodgrass. "This data set will be very useful to look for evidence of small outbursts, for example, as Rosetta is now seeing frequent events and we would like to know whether they are detectable from Earth."

While 67P is now fading as seen from Earth, Rosetta will keep its watch around the comet until September 2016. It'll gather more data and produce ever more detailed images of the surface as it orbits closer to its cometary companion over the coming months. For project scientist Matt Taylor it's clear there's still plenty more excitement to come.

"Basically, we've done the first half, we've had our cup of tea and a couple of orange wedges and now we are ready for the second half," he says. "It's going to be a blinder." ☼

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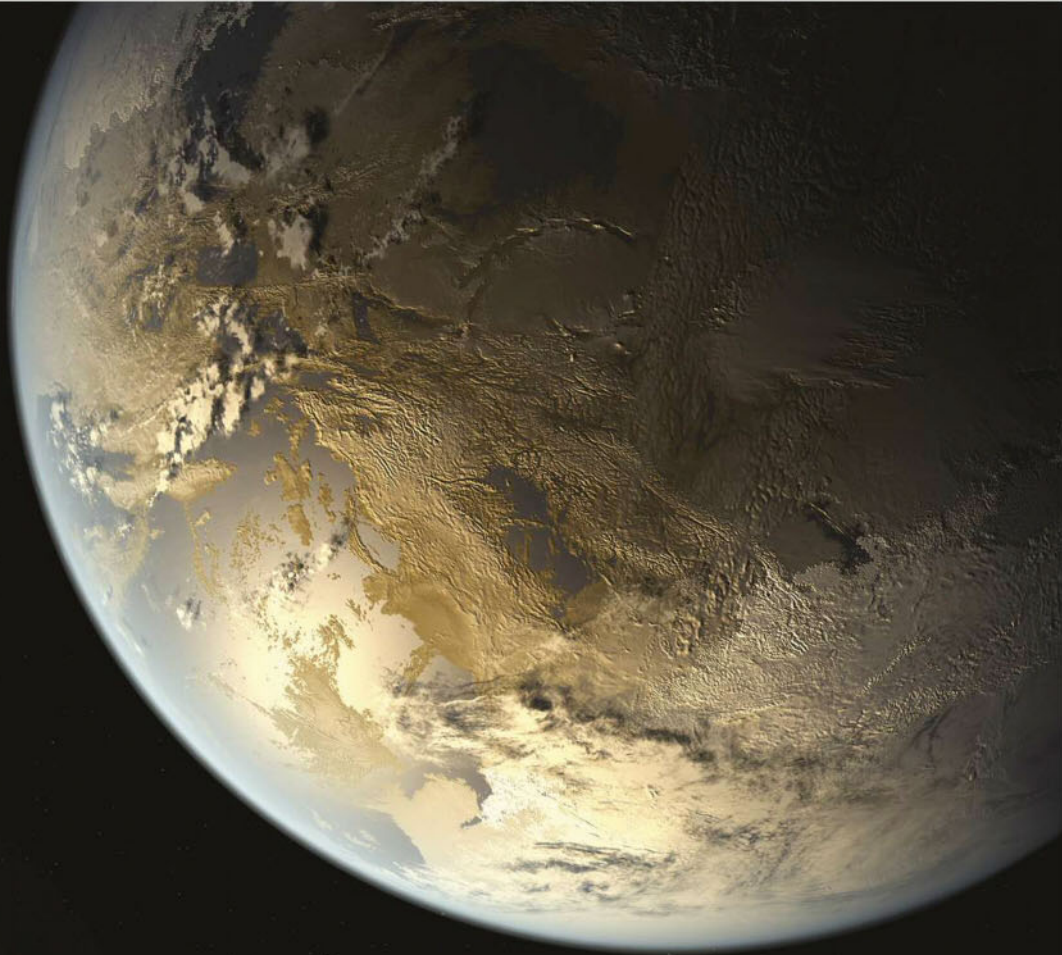
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Kepler 186f is an Earth-like planet discovered in 2014; this is our best guess of what it might look like, but it is still conjecture (Tim Pyle)



THE ART OF SPACE IMAGING

How do scientists create artwork of planets that no-one has ever seen? **Rob Banino** asks a visualisation scientist and a NASA graphic artist to get the inside story

Translating invisible light into shades the human eye can perceive is hard enough, but what happens when you have no visual reference whatsoever for the object you've detected? What do you do when the only way to spot that object is by the tiny amount of light it blocks out? How do you shed light on something when confirming its presence relies on darkness?

That's the challenge that faces astronomer and visualisation scientist

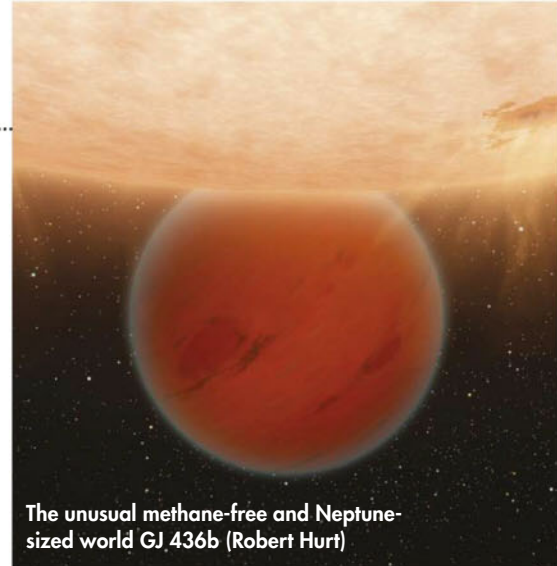
Robert Hurt and Spitzer Science Center graphic artist Tim Pyle. They're charged with envisaging the exoplanets detected by NASA's Kepler mission – planets that lie so far beyond our Solar System they can only be spotted by the effect they have on the stars they orbit.

"We're not actually seeing light from the planet in Kepler's detections, we're just seeing how much of the star's light these planets are blocking. There's no other intrinsic information," explains

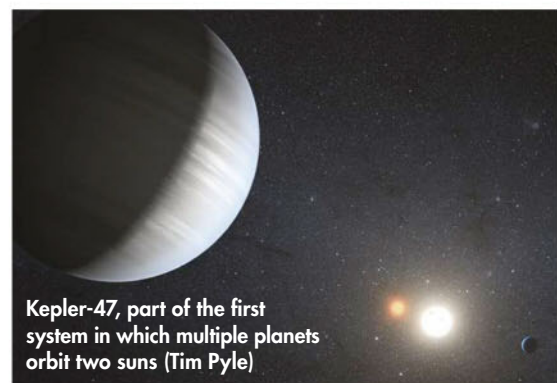
Hurt. "But once you know the planet's there, you can observe it with other telescopes – Spitzer, for example, which works with infrared light. And by measuring how big the planet appears to be at different wavelengths of light you can start to make deductions about what may be in its atmosphere, as different molecules absorb light at different wavelengths... But we don't actually see the planet. We don't actually see the star." ►



The unnamed gas giant that may have regained its infrared glow from white dwarf PG 0010+280 (Robert Hurt)



The unusual methane-free and Neptune-sized world GJ 436b (Robert Hurt)



Kepler-47, part of the first system in which multiple planets orbit two stars (Tim Pyle)



“We come up with what would be a plausible set of properties for a planet of this size” Robert Hurt

► But if there's nothing to actually see, how do we get the images that accompany the announcement of each new exoplanet discovery? The short answer is Hurt and Pyle collaborate with NASA scientists to create them.

“There are subtle clues in the data and the scientists deduce the information Tim and I need [to create an image],” says Hurt. “How big the planet is, how far away it is from its star, how hot it is

and so on. We work out what we can say with confidence about the discovery and we get a list of science topics that we want to embody in the artwork.

“It's very speculative but what we do is try to come up with the best set of insights into what would at least be a plausible set of properties for a planet of this size, in this location and in this kind of system.”

Pyle also reiterates the speculative nature of their work. “We can never

illustrate exactly what a given planet looks like because we can't say for certain. For instance, in the case of Kepler-186f [the ‘Earth-like’ planet discovered in April 2014], we couldn't say if it definitely has water but, based on all the information we have, there's a likelihood that there's water on the surface. So we're really illustrating probabilities.”

The scientists interpret the data, then Hurt and Pyle extrapolate from those

THE ART OF IMAGINING EXOPLANETS

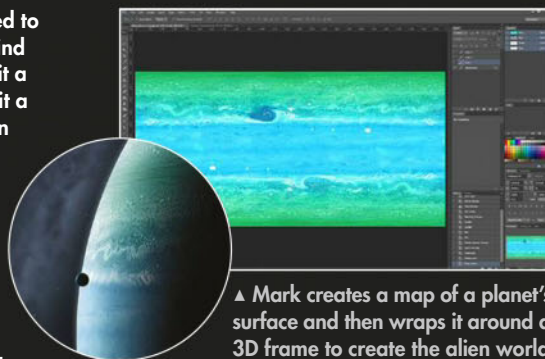
Space illustrator Mark Garlick reveals how he creates his own exoplanet artwork



“First of all, I need to establish what kind of planet it is. Is it a rocky planet? Is it a gas giant? Is it an ice giant? That's the most basic information that

I need. But then within those types I need other information. So if it is a rocky planet, is it Earth-like? Is it covered in oceans? Rocky planets differ massively. Think of Mars, Mercury and Venus: these are all rocky, but are all totally individual and different.

I base my images on depictions of the planets we can already see within our own Solar System. If you are drawing a gas giant, for example, there aren't going to be a huge amount of different ways it can appear. It's probably going to be rotating rapidly, so you



▲ Mark creates a map of a planet's surface and then wraps it around a 3D frame to create the alien world

will have cloud bands stretched around it. The only attribute I really have to play with is what colour the cloud bands are going to be, how thick they might be, and whether or not they are completely smooth like on Saturn or whether they're broken up and stormy like on Jupiter, where you have lots of individual

storm systems with swirls and vortices. It's usually not particularly difficult for me to come up with something that the scientists are happy with, working within this framework.

These days, very little pencil to paper drawing is done. I create my drawings of planets mostly using a 3D computer program. So for example, if I had to create a gas giant, rather than drawing a sphere and then painting the cloud bands on, I would begin with a map. I would create a rectangular section and then paint on horizontal stripes to create the clouds. Then I would add all my detail to create the texture of the planet. Once I am happy with it, I move it into a 3D program and wrap the map around a spherical shape to create the illusion of a cloud band swirling around a planet. With these techniques, we can do a lot more nowadays in a shorter space of time than we could 20 or 30 years ago.”

interpretations to create the illustrations we are so familiar with. So although the pair's artistic skills are important, they must exercise them judiciously.

"We try to be really responsible about what we show in these artist concepts," points out Pyle. "All of our decisions are vetted by people at every stage of the graphic's development. With the artist concept of Kepler-186f for example, we went through multiple iterations so people could say "Well, it still looks a little too much like Earth so we need to pull back on this or that," and then continued until everyone felt comfortable with what we were showing."

Staying grounded

Once again, it's a question of balance – Hurt and Pyle must do all they can to produce fascinating images without allowing them to become outright fantasies. The images need to be arresting enough to attract people's attention while retaining as much authority as possible for a speculative artwork.

"What we're trying to do is make sure there's enough science in the artwork to enable an understanding of the story," says Hurt. "We're trying to engage people, but if we do so with something that's a lie then we're working against the result. We need to engage

them with something that's consistent with the results. That's our goal: to work on both levels."

But given the guesswork and artistic licence taken with these exoplanetary images, do they actually hold any scientific value?

"The artwork offers a quick shortcut to understanding that is helpful for communicating

these ideas to the public," Hurt explains.

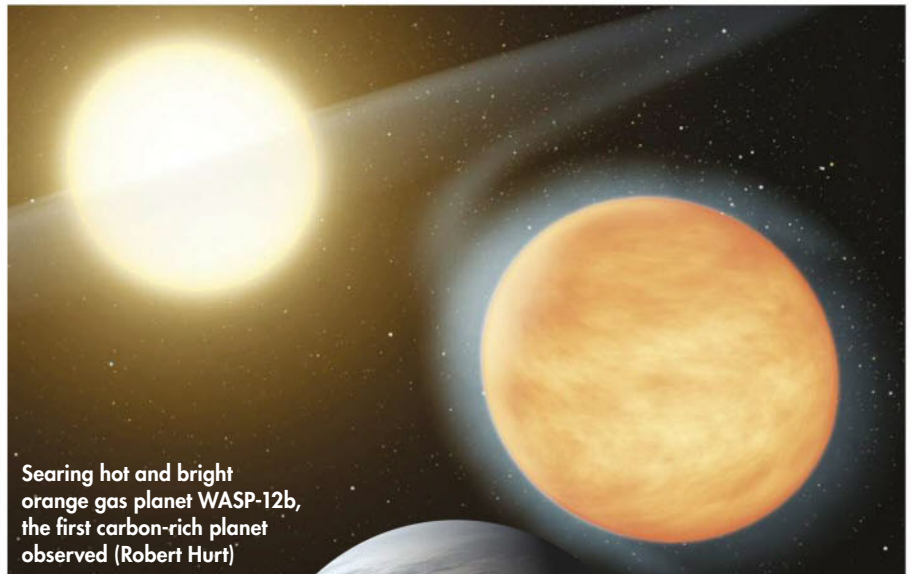
"But even the process of developing these possible scenarios engages the scientists doing the research to combine their observations with the best current theories of planetary science.

"Naturally in time much of this artwork will be proven to be incomplete or inaccurate, but they will stand as a visual

record of an evolving understanding of the nature of exoplanets. What today is a visual tool for education and communication, tomorrow will be part of a visual tapestry of the history of exoplanet science." **S**



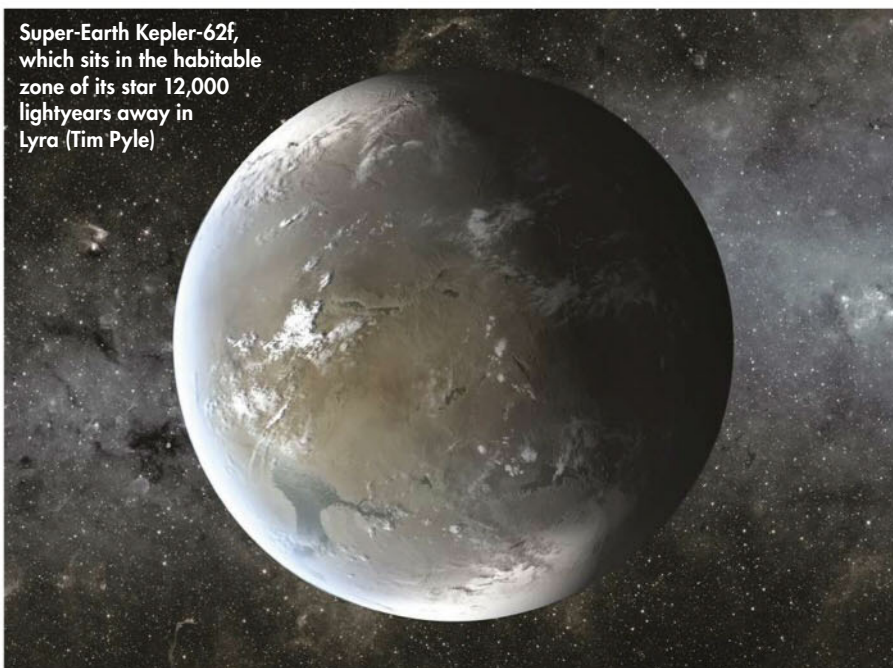
"We try to be really responsible about what we show in these artist concepts" Tim Pyle



Searing hot and bright orange gas planet WASP-12b, the first carbon-rich planet observed (Robert Hurt)



▲ Kepler-69c, a super-Earth planet in Cygnus (Tim Pyle)



Super-Earth Kepler-62f, which sits in the habitable zone of its star 12,000 lightyears away in Lyra (Tim Pyle)



ABOUT THE WRITER

Rob Banino has spent the last 12 years working as a journalist. He has also worked for *BBC Sky at Night Magazine's* sister science title, *BBC Focus*.



▲ Tiny exoplanet UCF-1.01 is so close to its star it may have a molten surface (Robert Hurt)

NASA/JPL-CALTECH/R. HURT (IPAC), NASA AMES/JPL-CALTECH/T. PYLE X 3, MARK GARLICK X 2
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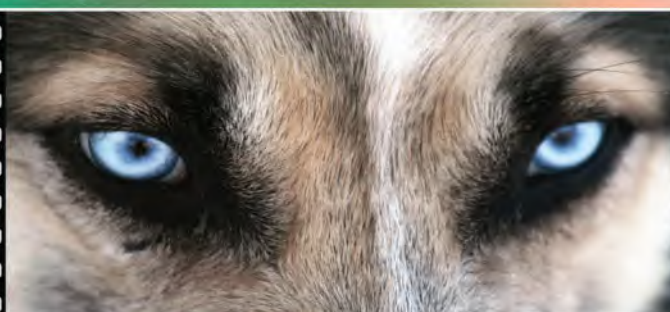
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HURTIGRUTEN

The first ISS crew arrived in 2000, and the station has been manned ever since



15 years ON THE ISS

November 2015 marks the 15th year of continual occupation of the International Space Station. **Matthew Cox** spoke to astronaut Scott Parazynski to find out what life is like on board

The ISS has seen a lot of change over the decade and a half it has been in orbit. The first components were launched from Kazakhstan in 1998 and, just two years later, the inaugural crew arrived and began to set up equipment and provide for further supply visits. 2001 saw the arrival of Dennis Tito, an American businessman who reportedly paid \$20m to be the first private citizen to go into space, staying on the ISS for six days with two Russian cosmonauts. The Columbia disaster in 2003 led to the grounding of the Space Shuttle fleet for two years, which also disrupted supply missions, but the station steadily

expanded and the ISS was finally completed in 2011.

For astronauts arriving on board the ISS, signs of occupation are immediately apparent.

"We have wonderful mock-ups on the ground and also virtual systems in the labs that allow us to fly through the station. We think we have a very good sense of what the place will be like but it's very different when you arrive," says Scott Parazynski, a NASA veteran who made five spaceflights in his 17-year career including visits



▲ Scott Parazynski is a veteran of five spaceflights

to the station in 2001 and 2007. "For a start, there are laptops, cameras, cables, experiments and even snacks positioned on every available surface. There's stuff everywhere. So you don't see the pristine view of the ISS as it appears in our VR labs on the ground."

Parazynski trained as a medic before joining NASA in 1992 and has no doubts about the best part of being on the ISS. "As a spacewalker my favourite environment was around the space gear. Being around

The first ISS module to be launched was Zarya in 1998; originally the sole source of power and propulsion, today it is only used for storage



One of the ISS's most famous visitors was Dennis Tito, the American multimillionaire who became the first tourist to go to space in 2001



Parazynski talks to cosmonaut Yuri Usachev aboard the Russian Zvezda module



the suits, being in the airlock of the station, getting tense before going outside – that was always my favourite part. Floating out of the hatch, there's just nothing in the known Universe as cool as that."

Bonding with the crew at meal times was also a memorable part of the daily routine. "The schedule's always flexible," he says. "Even though Mission Control has plans well laid out, if we have to troubleshoot something, the whole day can get turned on its ear. But for the most part, breakfast and dinner were common times for us to get together. We'd convene in the Russian segment – they had a really nice kitchen table – and the cosmonauts would typically have some folk music playing in the background. You felt like you were in a Russian dacha."

He's also clear about how he preferred to unwind at the end of the day. "More or less every free moment you have, you're going to want to spend it by the window. It doesn't matter whether it's orbital day or orbital night, there's so much to see. So we tended to get our day started early and then hopefully have an hour or two at the end to listen to music and look out of the window."

Less weight, less sleep

Crew members on the station are also fortunate to have a particular advantage over everyone back home. "One of the beauties of being in space is that you don't need as much sleep as you do on Earth. You aren't doing the same physical workload because you don't have to carry

Parazynski steps out of the airlock into the blackness of space on STS-120 in 2007, his fifth spaceflight



your own body weight around. There's an adrenaline and fluid shift that occurs in the body when you fly to space but, in general, your heart rate returns to baseline once you adapt and it doesn't need to pump against gravity."

But when it is required, getting a good night's rest can still present its own unique challenges. "It's quite noisy in the main part of the station," says Parazynski, "but the sleep quarters have better noise isolation. There's a constant white noise ▶



▲ ISS crew members use Velcro to hold their heads against their pillow for a good sleep

► plus a cabin fan that circulates the air and cools all the avionics. It's a kind of soothing sound. The more interesting challenge when sleeping is the lack of physical contact with some structure. Our sleeping bags have a pillow built into them, which is a little odd as we don't have gravity to hold our heads to the pillow. But we use a Velcro head strap and that sense of contact somehow psychologically gives you the grounding to then fall asleep."

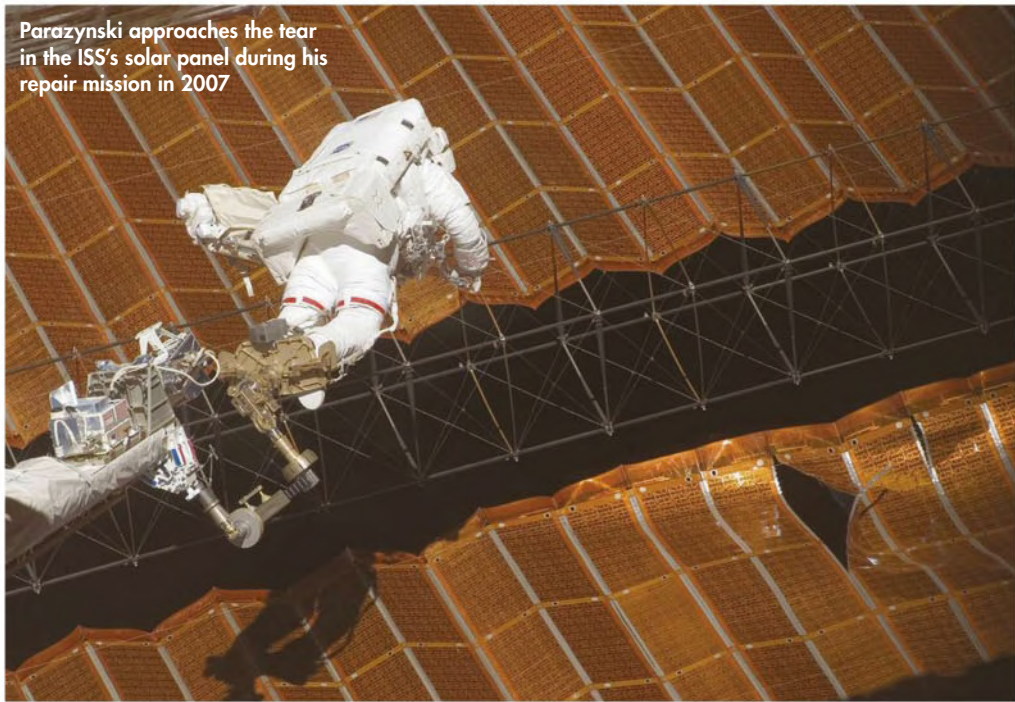
Despite the close confines and pressures on the astronauts, arguments appear to be rare. "There's conflict resolution in everything we do in life so I guess it's a matter of how we handle disagreement," Parazynski says. "Astronauts and cosmonauts have the same mission focus and a general background in challenging environments, but actually the cultural differences are quite significant. We've had astronauts on the ISS from Japan, Canada, Brazil, Israel and all over Europe. But I wouldn't say I've ever seen or been a part of any strongly worded argument. It's a very democratic and consensus-building type of environment. But, if there's a life-critical situation going on, then whoever was in the heart of the situation would have to make a split-second decision to do something. That's really uncommon though."

When plans go wrong

Parazynski is certainly no stranger to difficult situations. During an ISS mission in 2007 he was involved in what has been described as one of the most challenging spacewalks ever attempted. When a solar panel failed to open correctly, the crew had to make a series of improvised connectors that were used to repair a tear so the array could open to its maximum size.

"It was certainly a spacewalk where we didn't have confidence that it would necessarily succeed. There was a chance we

Parazynski approaches the tear in the ISS's solar panel during his repair mission in 2007



▲ Arguments are rare on the ISS despite the close quarters and varied cultures of the crew

might have had to go on to a Plan B or Plan C. Mission Control were looking at other ideas, one of which was to throw away a billion-dollar asset, the solar panel, which would have been devastating, quite honestly."

The ride out to the repair site was further than any previous spacewalkers had ventured from their airlock and involved adding a 15m extension from the Space Shuttle Discovery onto the end of the robotic arm of the ISS. Two crew members controlled the robotic arm that brought Parazynski into position and, because of the risks posed by hot circuitry, he had to wrap insulating tape around the tools and over the metal rings on his spacesuit. Had there been a problem that caused damage to Parazynski's spacesuit, it wasn't clear whether his colleagues would have had time to return him to safety.

"It was all about me trying not to screw up when everyone had done such a great job, up until the point where I had to finish the work. But I was able to reflect



▲ Parazynski peers into the ISS during the first spacewalk of his first mission to the station

back on my training and thankfully it went extremely well."

Unlike some crew members, Parazynski knew in advance which mission would be his last to the station. "Having the knowledge that it would be my last flight to the ISS was really valuable and I took lots of extra photographs. But it doesn't always work out that way. Some people develop a health issue or they just don't have the luxury of knowing if they'll be going back into space again. It was a good moment for an old timer like me to get out of the way. The young guys also made it clear that it was time for me to go as well. They were certainly forthcoming about that!" **S**



ABOUT THE WRITER

Matthew Cox is a freelance journalist who writes on science issues and a keen observer living near dark skies in Hertfordshire.

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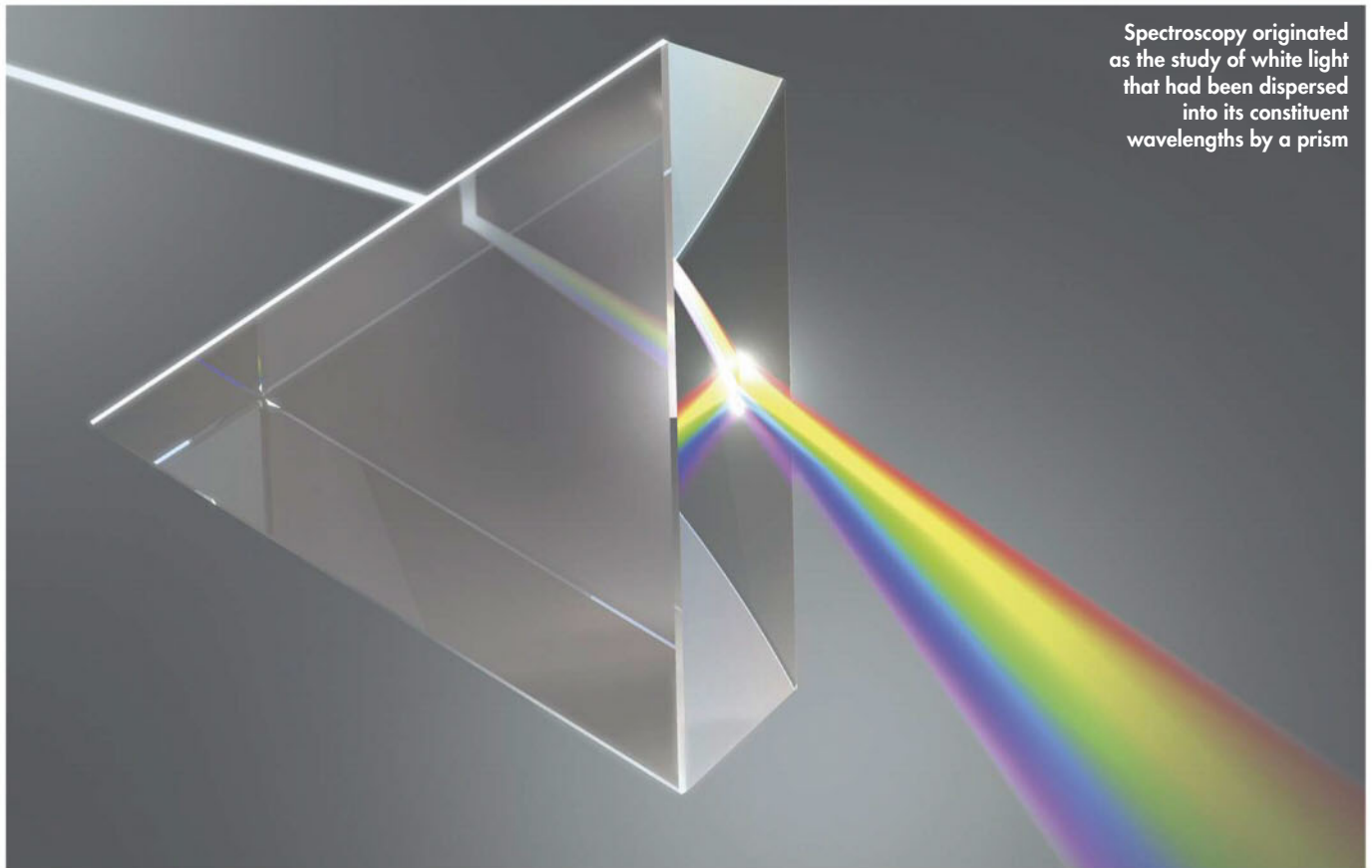


The Guide

Understanding spectroscopy

With **Olivia Johnson**

Examining starlight can teach us a great deal about the Universe



Spectroscopy originated as the study of white light that had been dispersed into its constituent wavelengths by a prism

One of the wonders of astronomy is that we are able to learn so much about our Universe by studying only the light that reaches our telescopes from distant cosmic objects. This marvellous feat would be impossible without spectroscopy, the study of the interaction between light and matter.

In spectroscopic observations, light is dispersed into a spectrum using a prism or a diffraction grating, so that the amount of light seen at different wavelengths can be compared. Early spectroscopic studies identified three basic types of spectra. Continuum spectra exhibit a smooth distribution of light with wavelength, like the rainbow produced by a prism. Absorption spectra feature a smooth

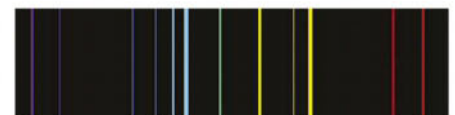
continuum with some wavelengths missing; these dark gaps are called absorption lines. Conversely, emission spectra contain only bright lines at specific wavelengths.

The secrets of starlight

We now understand these features in the context of atomic physics. Light can be absorbed and emitted by atoms, but only at wavelengths whose energies correspond to the gaps between the energy levels occupied by electrons within atoms. These energy levels are specific to each chemical element, so patterns of spectral lines comprise a chemical fingerprint that can be used to identify which element is absorbing or emitting the light. Continuum emission results from

interactions between matter and radiation that aren't constrained in this way, such as thermal processes.

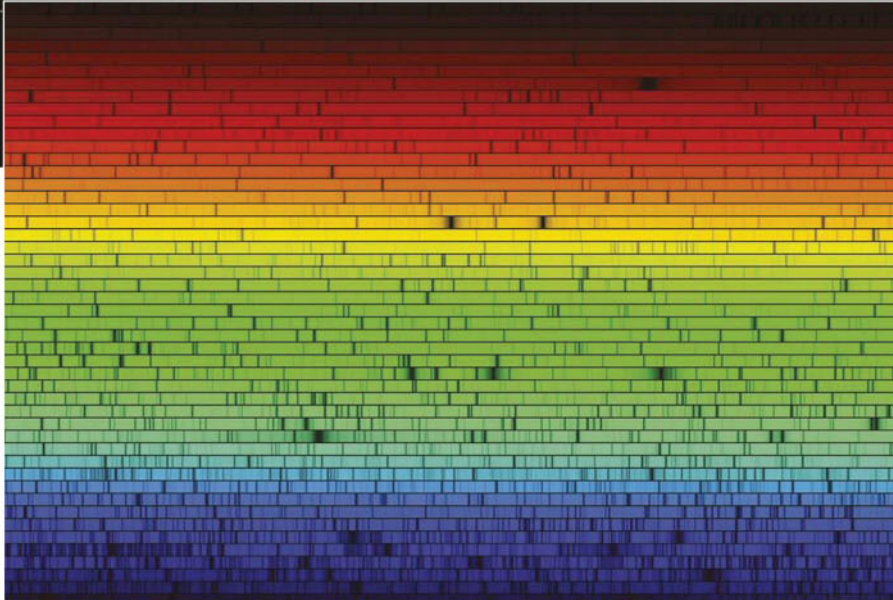
Long before the atomic nature of matter was understood, 19th-Century spectroscopists determined the chemical



▲ Emission spectra only show coloured emission lines indicating elements that are present



▲ Absorption spectra are characterised by black lines in an otherwise continuous spectrum



▲ Spectra act as stellar 'fingerprints' – this one of the Sun reveals its chemical composition

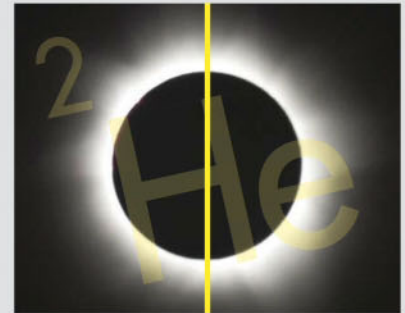
composition of the Sun's atmosphere by comparing the wavelengths of absorption lines in the solar spectrum with those identified in laboratory experiments. Determining the chemical composition of stars – and of nebulae, galaxies and planets – remains a key goal of spectroscopy today. In addition, systematic studies of large numbers of spectra have yielded classification systems and evolutionary models that allow us to estimate of other parameters – for example, stellar age – from the observed chemical abundances.

Spectroscopic observations also reveal how objects in space are moving. If a light source is moving away from us – or if the space between us and the source expands as the light travels through it – we observe it to have a longer, redshifted wavelength. When a light source moves towards us, we detect shorter-wavelength blueshifted light. Spotting a familiar spectral signature at a different wavelength than expected

implies the source is moving (or that space has expanded) and we can calculate its velocity (or the extent of the expansion) from the difference in wavelengths.

This powerful technique underlies many fundamental discoveries in astronomy. For example, measurements of galaxy spectra revealed that light from more distant galaxies was more strongly redshifted. We now know this reflects the expansion of the Universe over cosmological time, and we use spectroscopic measurements of galaxy redshifts to determine their distance and age. On smaller scales, we use spectroscopic observations of stars to detect binary companions and exoplanets. The small gravitational tug these satellites exert on a star causes it to wobble and produces a measurable periodic change in the wavelength of its spectral features. **S**

Olivia Johnson is an astronomer specialising in science education



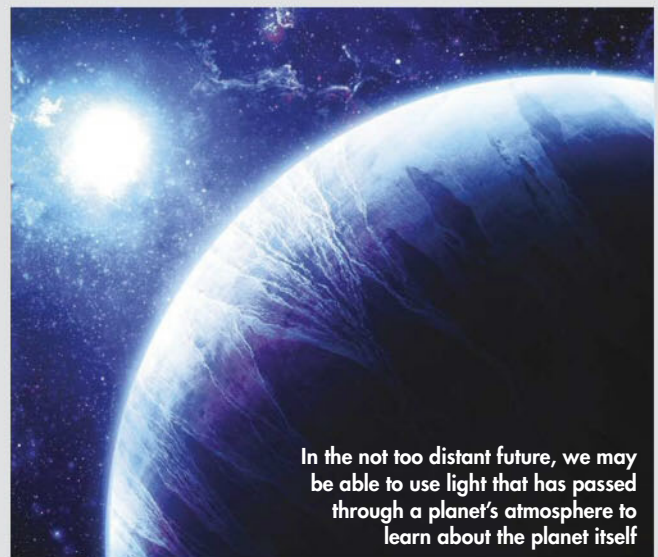
▲ The yellow line of helium spotted in 1868 was mistaken for sodium at first

THE UNEXPECTED ELEMENT

To date, no elements have been discovered in spectroscopic observations of the cosmos that do not occur naturally on our planet – though one common one was discovered in spectra first. Systematic studies of the spectral lines associated with different elements were already well underway by 1868, when a bright yellow emission line was observed during a solar eclipse. This was initially thought to be an emission from sodium, which produces two other lines nearby in the spectrum. Yet further study of the new line, detected in the solar spectrum a few months later, showed that it was not associated with any element then known. This mystery element was named helium, after the Greek word for the Sun. Though it is the second most abundant element in the Universe, it would be 14 years before it was observed on Earth and another 13 years before it was produced in a lab.

EXPLORING ATMOSPHERES

In coming years, spectroscopic observations could deliver another ground-breaking scientific achievement – the detection of extraterrestrial life. Exoplanets may seem unpromising targets for spectroscopic study as they produce no light of their own. When they transit in front of their host star, however, absorption features should appear in starlight that has travelled through their atmosphere. Astronomers hope to be able to detect the presence of biosignature gases, such as oxygen or methane, which are byproducts of life here on Earth. Some scientists even suggest that spotting traces of industrial pollution could provide evidence of an advanced alien civilisation. Studies of this type are still in their infancy, and there are currently few suitable targets within the capabilities of our telescopes. However, extremely sensitive space telescopes due to launch soon should be able to both detect dozens of nearby exoplanets that are analogous to Earth and have the capability to study their atmospheres spectroscopically.



In the not too distant future, we may be able to use light that has passed through a planet's atmosphere to learn about the planet itself

Meteorite

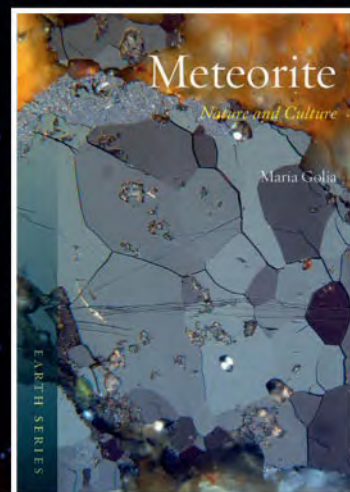
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With Andrew Gilhooley

How to Make a pipe spectrometer

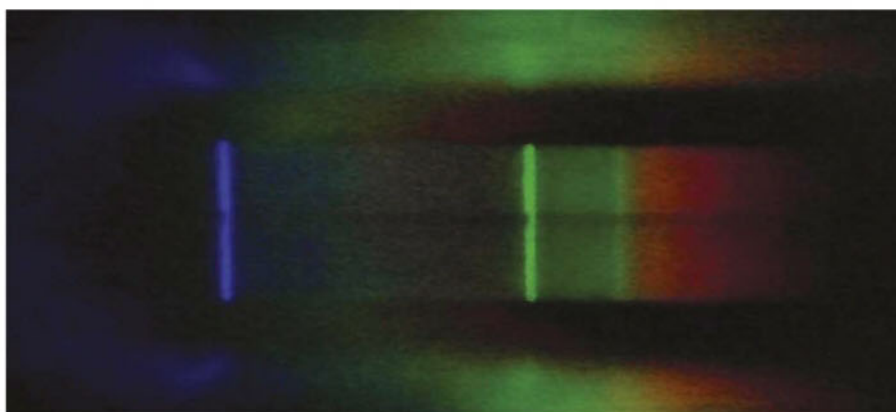
See the spectrum of the Sun for yourself with this DIY device

WARNING

Do not look directly at the sun with the naked eye or through any optical device that has not been fitted with the appropriate solar filters



▲ Aiming the spectrometer slightly away from the Sun will make its spectrum easier to see



▲ You can test the spectrometer on artificial light sources – this is the pattern of fluorescent lighting

Isaac Newton used the term 'spectrum' to describe the rainbow of colours revealed when white light is refracted through a prism. We can use spectra to determine the chemical composition of astronomical objects by analysing the pattern of vertical lines within them, using a device called a spectrometer. Early spectrometers used prisms to split the light by refraction, however for this project we will make a pipe spectrometer that uses a holographic

diffraction grating for the same purpose, in order to reveal the spectrum of the Sun. This is a fun, simple and safe exercise that reveals an aspect of the Sun that is not frequently observed by amateurs, and also shows that different light sources do not shine in the same way.

Both types require an 'entrance slit' that vignettes the light as it enters the spectrometer. Once the incident light has passed the entrance slit, it diverges and is then passed through the diffraction



TOOLS AND MATERIALS

MATERIALS

40x1500mm black solvent weld waste pipe, 130° black solvent weld bend, 40mm black solvent weld access cap, 40mm black pipe connector, 150x300mm diffraction grating (1000 lines per mm), opaque black plastic DVD case.

TOOLS

Rotary Multi-Tool with a sanding drum and a cutting wheel, hacksaw, heavy-duty scissors.

SUNDRIES

Safety glasses or goggles, tape measure or ruler, extra strong clear adhesive.

grating, which disperses the light at slightly different angles. These differing angles produce the spectrum – the cascade of colour so similar to what we see when a rainbow appears in the sky.

A 'continuum' spectrum is a band of colour ranging from violet through to red, and is produced by all incandescent solids, liquids and gases under pressure. An 'absorption' spectrum occurs when light passes through a gas; the atoms that make up the gas absorb photons of specific frequency dependent upon the type of gas, resulting in the appearance of dark lines within the spectrum. These bands are the Fraunhofer lines, named after the German physicist Joseph von Fraunhofer, although he cannot claim the initial discovery. ►

► Starting in 1814, Fraunhofer identified over 570 individual lines representing the chemical composition of the Sun. There are now known to be over 25,000 absorption lines within the solar spectrum.

The final type is an 'emission' spectrum, the result of a specific chemical element or compound absorbing then re-emitting radiation. When an atom transitions from a high-energy to a low-energy state, a photon of a specific frequency is emitted. The frequency of that photon is dependent upon the element which makes up the material emitting the radiation. This results in the appearance of bright lines, with the remainder of the spectrum dark.

Getting the right fit

Building this spectrometer requires some cutting with both a saw and scissors, and the use of a rotary multi-tool with both a sanding drum and a cutting wheel. Always be sure to wear the safety spectacles or goggles when cutting and using the rotary multi-tool. Before gluing, test all components to ensure they fit. A reasonable fit is required – not too tight and not too loose. The diffraction grating is sensitive to bowing or pinching, which can occur if the fit is too tight, however you do not want any stray light leaking through because the components are too loose.

This project uses no lenses or other methods of light concentration. There is no direct observation of sunlight, only of the diffraction grating. Do not attempt any modification of this project to involve lenses, mirrors or any other form of light concentration. Direct observation of the Sun is dangerous – never look at the Sun through binoculars, or a telescope without specialist equipment, as your eyesight will be permanently damaged.

For the best use, do not point this spectrometer directly at the Sun as it will wash out the dark lines. Pointing it slightly away from our star will reduce the glare significantly. This will reveal an absorption spectrum, with dark bands. For comparison, a fluorescent strip light will reveal an emission spectrum showing bright bands in the green and violet. These are the emission lines of the mercury vapour and phosphor in the tube. An incandescent light bulb will reveal no banding whatsoever: the tungsten filament is the solid being heated to produce a continuous spectrum. **S**

Andrew Gilhooley conducts solar viewing outreach sessions with Sheffield AS

STEP-BY-STEP GUIDE



STEP 1

With the saw, cut the pipe to a length of 380mm. Clean up the newly cut end using the rotary tool's sanding drum. Use the diameter of the pipe as a template to cut two 40mm discs from the DVD case.



STEP 2

Using the rotary tool's cutting wheel, cut an entrance slit of 25mm in one of the 40mm discs. Inside the pipe connector, there is a small lip. Glue one side of this lip, and insert the disc with the entrance slit into the glue.



STEP 3

The access cap acts as a dust cap for the spectrometer and comes in two parts – a cap and an adaptor. Glue the adaptor, and then insert this into the pipe connector on the same side as the entrance slit.



STEP 4

Hollow out the second 40mm disc to no more than 35mm. This supports the diffraction grating. Cut a 40mm piece of grating to match this part and then carefully glue them together. Make sure no glue spills on to the central part of the grating.



STEP 5

Fit the entrance slit assembly into one end of the 380mm pipe. At the other end, the diffraction grating is sandwiched between the end of the pipe and the 130° bend connector but do not glue at this stage. Aligning these components is critical to the spectrometer's performance.



STEP 6

Line up the spectroscopy with a light source, handholding the diffraction grating by its edges. Looking into the grating at an angle while rotating it will reveal the most appropriate position. Fit the 130° bend when the spectrum appears acceptable.

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With **Steve Richards**

Image PROCESSING

Using flat frames to calibrate your astrophotos



▲ Our final image of the Orion Nebula, after a master flat calibration and some additional processing to pull out detail in Photoshop

Capturing deep-sky images isn't just about using a camera, mount and telescope – equally important is the processing of turning your hard-won data into a masterpiece that you are proud to show to other people. This process starts with calibrating your images to remove noise and other unwanted artefacts.

The technique of applying flats causes the most angst among astro imagers, yet when correctly used they can transform your photos. Flats can remove the dark shadows cast by dust motes, correct the light fall-off towards the edges of the field of view caused by vignetting and will compensate for variances in pixel sensitivity across the camera's sensor.

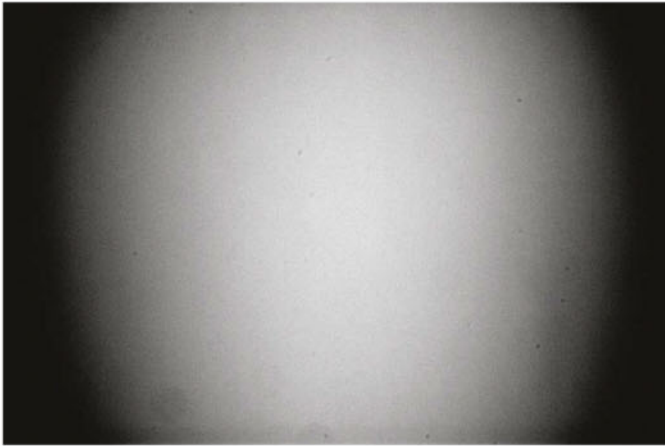
Flat frames must themselves be calibrated and stacked to avoid the risk of introducing artefacts of their own. So, the first stage in applying flats is to calibrate them with bias frames, which are image frames taken with the telescope's dust cap installed and with as short an exposure as the camera will allow. This calibration removes some of the 'noise' generated by the process of downloading the image data from the sensor by a process of subtraction.

You should collect around 20 flats, but instead of applying these to your images you should stack them into a single 'master' flat frame. Using a master flat speeds up the process of calibration but also increases the signal-to-noise ratio,

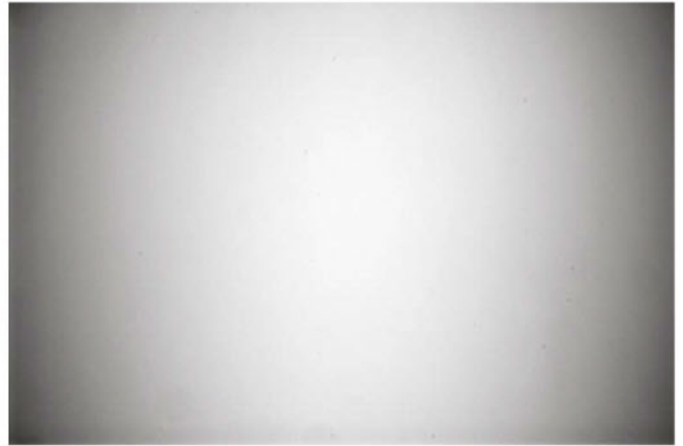
ensuring that your flat doesn't impart any unwanted noise of its own.

Stack for a better result

The manner in which the flat frames are calibrated, stacked into master frames and finally applied to the image data depends on the software in use. For example, MaxIm DL produces all its calibration master frames in advance by selecting Process > Set Calibration and then choosing the folder that contains the calibration files. Once selected, simply clicking on the Replace W/ Masters button will produce a complete set of master bias, dark and flat frames automatically depending on the contents of the folder. In DeepSkyStacker on the other hand, the



▲ Single flat frames often show vignetting and artefacts of their own



▲ Producing a stacked master flat will remove many of these blemishes

calibration files are selected along with the image data files by clicking Open Picture Files and selecting in turn, your image, dark files, flat files, dark flat files and finally, offset/bias files from their respective folders. The individual files are then enabled for further processing by clicking on Check All.

The 1.34-second flat frame shown above exhibits both large and small dust shadows – the smaller blemishes indicate dust particles close to the sensor and the larger ones the particles farther away from it. The light fall-off to the edges of the field of view can be very clearly seen, but so too can the relatively low signal-to-noise ratio.

The image on the top right shows a master flat frame, and the improvement is clearly visible. This master flat is comprised of 20 individual exposures, each of which has been bias frame subtracted before stacking. As a result it is much smoother and has a considerably higher signal-to-noise ratio, just right for calibrating the image data without adding any noise of its own.

With a master flat now prepared, this can be applied to the image data, however, whereas bias and dark frames are subtracted, flat frames are divided into the image data by a complex piece of mathematics that is taken care of by the image processing software.

Using MaxIm DL, the flat calibration is automated within the stacking process. Select Process > Stack > Add Files and then choose the files you want to process by browsing to their folder. Tick the Auto Calibrate check box, click on the Align tab and choose Auto – Star Matching. Click on the Combine tab and choose SD Mask, and finally on the Go button. The image frames will be calibrated and stacked to produce your single image that you can save as a 16-bit TIFF file ready for final processing in Photoshop or another image processing



▲ M42 before flat frame calibration, adjusted using only the Levels tool – though the image is bright in the centre, there is light fall-off towards the edges of the field of view



▲ The same shot of the Orion Nebula after a master flat frame calibration has been applied – now there is an even distribution of light intensity across the background night sky

package. If you are using DeepSkyStacker, the default parameters work very well. Simply select Register Checked Pictures and tick the Stack After Registering check box. Finally, click on the OK button to produce the calibrated and stacked image ready for further processing.

As you can appreciate, flat frames are a very important part of image

processing. The three stages of our image of the Orion Nebula on these pages reveal how much they can improve your shots, finally allowing you to bring out impressive detail in Photoshop as seen in the opening image. **S**

Steve Richards is a keen astro imager and astronomy equipment expert



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With **Steve Richards**

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► If a webcam is what you're after, a Philips SPC900NC is one of the best but is now only available secondhand



◀ However, for a dedicated imaging camera, the Celestron NexImage Burst is an excellent choice

I want to get into planetary imaging, but I'm not sure if I should buy a dedicated camera or adapt a webcam. Can you advise?

CLIVE JOHNSON

The quality of planetary images is very much dictated by the seeing conditions: the shimmering of light reflected from the planets as it passes through Earth's atmosphere smears the fine detail needed to produce high-quality results. There are brief periods of good seeing in which fine detail can be captured, but the problem is knowing exactly when the atmosphere will be still.

Luckily, the major planets are relatively bright so they can be photographed using very short exposures. By capturing long sequences of these short exposures, the chances of capturing an image during one of these good periods of seeing is dramatically increased. Once the data is captured, registration and

stacking software such as RegiStax or Autostakkert can be used to filter the best images and stack them into a single image ready for further processing.

The easiest way to capture numerous short exposure images is to use either a webcam or high frame rate camera designed specifically for astronomy use. Webcams can, however, be quite variable in quality so you need to choose carefully. If you can locate a secondhand Philips TouCam Pro 2 or SPC900NC webcam, either would be ideal. Meanwhile, high frame rate cameras have quietly instigated a revolution in planetary imaging over the past decade. Two to consider are the dedicated Solar System cameras ZWO ASI034MC or the Celestron NexImage Burst.

STEVE'S TOP TIP

What is a Bahtinov Mask used for?

Focus is the single most critical component of any successful image but it can be remarkably difficult to achieve. Despite the use of digital cameras and their live view features, determining when a test star is at perfect focus is rather subjective. However, the use of a Bahtinov Mask makes achieving accurate focus really simple.

Just as a Newtonian Reflector's spider vane produces diffraction spikes on bright stars, the 'vanes' on a Bahtinov Mask produce a complex diffraction resulting in a cross and a horizontal line. Adjusting focus until the line bisects the cross confirms perfect focus.



Use air bells to clean dust specks off of your CCD sensor

How do I clean my CCD sensor?

JON DAVIS

Rather like the mirrors in a reflecting telescope, you should only clean your sensor if you absolutely have to – don't think of it as a routine part of maintenance. However, unlike a telescope mirror, a little dust on the sensor's surface will show clearly in your images. Applying flat calibration frames will go a long way to resolving this but, prevention is better than cure.

Should you discover dust on your sensor, don't be tempted to brush it off with a lens brush, use a strong blast of air from an air bulb like a Hama 5610 Bellows Blower or Giottos GTAA1900 Rocket Air Blower. Compressed air canisters should be avoided, as these can be quite harsh and could place propellant on the sensor's surface.

Pollen can be very stubborn and in the presence of moisture can adhere to the sensor's surface. If this happens you can carefully remove it using Eclipse Optic Cleaning Fluid and Pec Pads.

Steve Richards is a keen astro imager and an astronomy equipment expert

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90

Find out what's behind the enduring appeal of the Orion Optics VX8 Newtonian



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This month's reviews



Tried & tested

90 Orion Optics VX8 f/4.5 Newtonian reflector



First light

94 Vixen AP-SM equatorial tracking mount



98 Baader Morpheus eyepiece series



Books

102 We rate four of the latest astronomy titles



Gear

104 Including this moon phase clock

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SKY SAYS...

The VX series is aimed at those who want a quality, easy to use telescope

Orion Optics VX8 f/4.5 Newtonian reflector

A stalwart scope to get your stargazing passion started

WORDS: PAUL MONEY

Orion Optics has been manufacturing telescopes since 1984, priding itself on producing quality telescopes using components manufactured or sourced in the UK. Here we take look back at its VX8 Newtonian reflector.

The VX series is aimed at those who want a quality, easy to use telescope. A range of apertures is available, from 6 to 20 inches, as are short or long focal ratios. The VX8 is an affordable yet lightweight system, and without accessories weighs just 7kg. It is constructed from a rolled aluminium tube finished in white with black trim and is supplied with tube rings and mounting bar. A straight-through 8x50 finderscope, ACU-2S 2-inch (50.8mm) Crayford focuser with a 1.25- to 2-inch adaptor and a cooling fan at the base completes the package.

When ordering you have the choice to upgrade the optics and add a mount, but our review is just of the basic telescope tube, which we found easy to attach to our own NEQ6 mount and quickly achieved balance. Using our own 25mm 1.25-inch eyepiece we aimed at the bright star Altair in Aquila, but initial testing showed the optics had slipped a little in collimation. Dropping in a webcam and defocusing to produce an Airy disc, we found that its concentric rings were offset to one side.

The primary mirror is supported by a nine-point cell with easy collimation and, after a few simple adjustments, we quickly had Altair pin sharp across 80 per cent of the view. At the edges there was a little coma where the stars take on the shape of a comet (hence 'coma') but this is to be expected in 'fast' systems with their shorter focal lengths.

Base appeal

With our 25mm eyepiece we found the slight effect of coma didn't greatly detract from our view of the Pleiades as it rose in the east, and the cluster was nicely framed with a hint of the Merope nebulosity visible. Turning to the Double Cluster in Perseus was equally rewarding. Swapping to a 10mm eyepiece, we homed in on the Dumbbell Nebula, M27 in Vulpecula. The nebula was bright and detailed whilst nearby M57, the Ring Nebula in Lyra, displayed a dark hollow reminiscent of its name. The galaxy pair of M81 and M82 over in Ursa Major were not ideally placed, but still glowed nicely in both our 25mm and 10mm eyepieces.

To test the scope's resolving power we used our 10mm eyepiece to view the stunning double star Albireo in Cygnus, and were not disappointed with its gold and blue components. However a better test was Iota Cassiopeiae. This is a tight triple star – we were able to split it using our 25mm eyepiece ▶

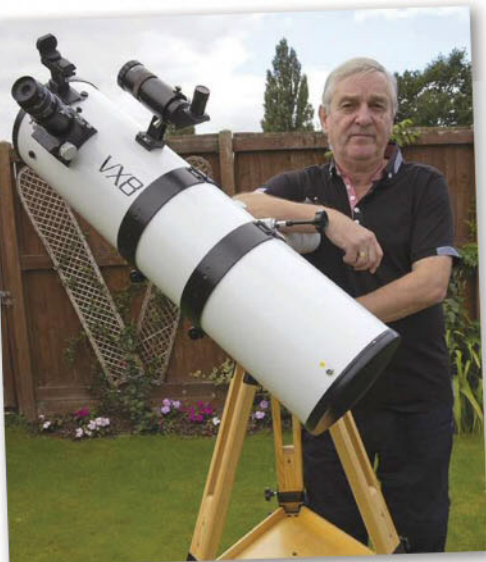
OWNER'S OBSERVATIONS

Name Mark Chamberlain
Location Hereford, Herefordshire
Telescope Orion Optics VX8 on a Sky-Watcher SkyTee-2 altaz mount and Berlebach UNI 18 tripod
Owner since November 2014

My VX8 f/4.5 Newtonian is four years old and has a one-sixth wave mirror with Hilux coating. As mine is older it has a single-speed Crayford focuser, not a dual-speed one. I have changed the collimation screws on the secondary mirror and use a correct image right-angled finder.

I am a keen deep-sky observer and wanted a quality 8-inch Newtonian as a grab and go scope to sit on my SkyTee-2/Berlebach setup. The VX8 is excellent for this purpose and as the scope only weighs 7kg it is easy to carry and set up. On my first night with it I viewed the edge-on spiral galaxy NGC 891 in Andromeda, which I thought was a good start.

The nine-point mirror cell is easy to collimate, and though it has a cooling fan I find that I rarely need to use it. I think the VX8 is a great scope with an excellent quality primary and secondary – I'm really happy that I bought it.



FINDER

The 8x50 straight-through finderscope gave good performance and clear views of the stars and brighter deep-sky targets. On ordering there is an option to upgrade to a right-angled finder.

LIGHTWEIGHT BODY

The rolled aluminium tube weighs 7kg and is only 86cm long, and as such we found it very easy to lift and attach to our chosen mount via the tube rings and dovetail bar. This means it can also be easily mounted on simple altaz mounts.



FOCUSER

The dual-speed ACU-2S 2-inch Crayford focuser has an extension that allows eyepieces to reach focus, and this can be removed for prime focus astrophotography. It gave very fine focusing control and can be tensioned or locked in position via a screw at the base.

OPTICS

The optical configuration is a paraboloid primary mirror at the rear with a flat secondary mirror at the front. They are made of low-expansion Suprax glass from Schott and the primary comes with a Zygo report detailing its optical quality.

TRIED & tested

SKY SAYS...

Now add these:

1. EQ5 SynScan Go-To mount
2. 25mm Tele Vue Plössl eyepiece
3. Orion Optics camera adaptor



COLLIMATION

The primary mirror is housed in a nine-point suspension cell, giving a high degree of recollimation capability if required. The cell is also fitted with a fan to help cool the mirror to the local ambient temperature, thereby reducing air currents in the tube that might spoil the view.



▲ The Double Cluster in Perseus, stacked from 51 one-minute exposures at ISO 800; note the slight coma to the stars compared to the image of M13 below



▲ The Moon, stacked from 42 exposures of 160th of a second at ISO 100



▲ M13, the Great Globular Cluster, stacked from 11 two-minute exposures

► and a 5x Powermate lens, but it does need good seeing conditions. It is worth noting that we could not split Iota Cassiopeiae until we had recollimated the scope, proving how important good collimation is.

Our final deep-sky target was globular cluster M13 in Hercules and on increasing the magnification we were delighted to see swarms of stars and the dark Propeller feature. There were no bright planets to view, but the Moon was crisp and full of detail at a range of magnifications with nice features viewed along the terminator.

Attaching our Canon EOS 300D and 50D DSLRs with our own adaptors we imaged several deep-sky objects, including the Double Cluster, the Dumbbell Nebula and M13 with very satisfying results. Our shots of the Double Cluster and Dumbbell Nebula were taken before we noticed the collimation was out (we had hurried to take advantage of a spell of clear weather) and the effects of the coma are more exaggerated compared with the image we took of M13 a few nights later, after we had performed our visual tests and recollimated. The Moon also proved a worthwhile target, showing lots of detail. In short, this is a nice telescope to get you started with both visual observing and imaging. **S**

VERDICT

BUILD AND DESIGN	★★★★★
EASE OF USE	★★★★★
FEATURES	★★★★★
IMAGING QUALITY	★★★★★
OPTICS	★★★★★
OVERALL	★★★★★

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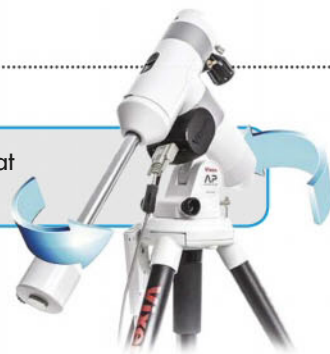
GIANT BINOCULARS FOR ASTRONOMY

FIRST light Vixen AP-SM mount

A no nonsense portable mount with a flexible modular design

WORDS: PETE LAWRENCE

See an interactive 360° model of this mount at
www.skyatnightmagazine.com/VixenAPSM



VITAL STATS

- **Price** £929
- **Load capacity** 6kg
- **Latitude adjustment** 0°-65°, northern and southern hemisphere
- **Coupling** Vixen/Synta dovetail
- **Hand controller** Star Book One
- **Autoguider port** ST-4 compatible
- **Weight** 3.9kg without counterweight, 4.9kg with counterweight
- **Supplier** Opticron
- **www** www.opticron.co.uk
- **Tel** 01582 726522

SKY SAYS...

We were impressed with how the mount kept its tracking accuracy without the autoguider

This month we've got our hands on a Vixen Advanced Polaris SM (AP-SM) mount, an equatorial tracking mount that combines elegance and grab-and-go functionality. Its modular design means it is a mount that can grow with your needs, and with its sleek appearance it will never look out of place at a star party.

The base AP-SM kit consists of the mount head, controller, connecting cables and counterweight. It needs something for it to sit on and for this task we used a Vixen APP-TL130 tripod. This is strong, lightweight and works beautifully with the AP-SM. Even with the 1kg counterweight attached, the AP-SM on this tripod is really easy to lift.

The base kit comes with a right ascension (RA) drive module installed but the declination (dec.) module is manual. A slow motion knob is provided for dec. adjustment. An optional upgrade is available which replaces the manual module with a driven version. Clever integrated connections in the mount then allow both modules to be controlled by a Star Book One hand controller.

The mount has a stated load capacity of 6kg and is stable enough for most operations in calm conditions. The drive units are powered either by 4x AA batteries inserted into the main body or via an external USB power source. The cover for

the internal batteries is easy to remove and also gives easy access to the mount's safety fuse.

Straight out of the box, the mount is fine for basic visual observing where a rough alignment on the pole star will do. The RA drive does a very good job of keeping things

in view but for more demanding tasks such as astrophotography you'll need to make a more precise polar alignment.

Sighting on Polaris

There are a couple of optional extras to help. The inexpensive route is a simple compass/altitude indicator that fits on an accessory shoe on the back of the mount body. More accurate alignment can be achieved using an excellent illuminated polar alignment scope which screws directly into the AP-SM's polar axis. This isn't a cheap option though.

The mount can be PEC (periodic error correction) trained to remove repeating errors inherent in the drive system. The PEC function isn't perfect though because the training data is lost when the mount is turned off. There's also facility to extend its tracking accuracy further by connecting its Star Book One controller to an external autoguider unit. ►

MODULAR DESIGN MAKES FOR EASY UPGRADES

The Vixen AP-SM is a beautifully designed modular mount. If you need to upgrade it for driven dec. movement, all it takes is a bit of DIY with a hex key and the default manual dec. module can be swapped with the optional driven version. Electrical connectors built into the mount ensure there are no unsightly wires to worry about either.

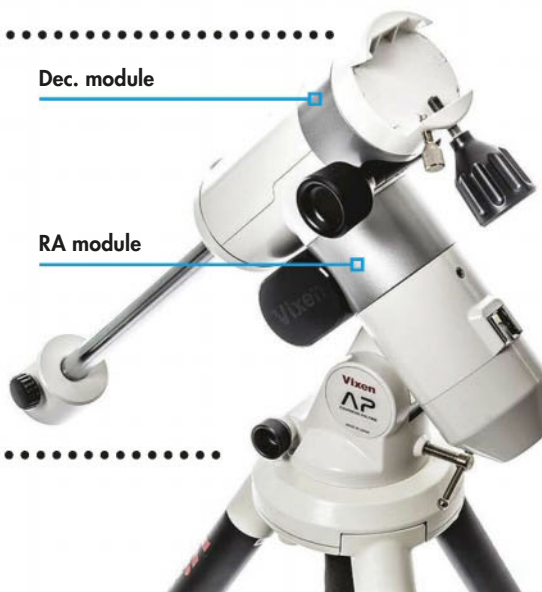
The mount is great with cameras and a simple Vixen tabletop tripod can be purchased in case you don't require the

more expensive APP-TL130 tripod we used for the review. It's worth mentioning that there's also an altaz version of the mount.

The design aesthetic is good across the board here. Little details such as the opening that allows the polar axis to see through the mount has a sliding cover on it and the hole in the mount is always open irrespective of the orientation of the dec. axis. The overall look of the mount system is elegant right down to the vanity cover that caps the end of the polar axis.

Dec. module

RA module





AUTOGUIDING

The Star Book One hand controller has an ST-4 compatible autoguider port at its base. An external autoguider needs to be plugged into this port for autoguiding functions to commence. Unless the optional dec. drive module is fitted, autoguiding only occurs in RA. The controller allows autoguiding adjustment speeds from 0 (off) to 99 (9.9x sidereal).

HAND CONTROLLER

The lightweight Star Book One controller complements the minimalist and elegant design of the mount. A clear, backlit LCD display makes it easy to read and interface with all the mount's functions. Buttons on the handset provide slewing controls. Tracking speeds of star, solar, lunar and 'king' (sidereal but accounting for refraction) are provided.

RA DRIVE MODULE

The RA drive module provides two connection ports and an on-off switch. One port is a nine-pin D-plug that connects the mount to the Star Book One hand controller. The other is a micro USB port into which external USB power can be supplied. The mount is very quiet, even when slewing at top speed.



FIRST light

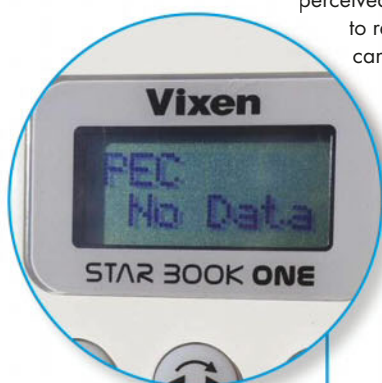
SKY SAYS...

Now add these:

1. Vixen APP-TL130 tripod
2. Motorised dec. module
3. Polar axis alignment scope

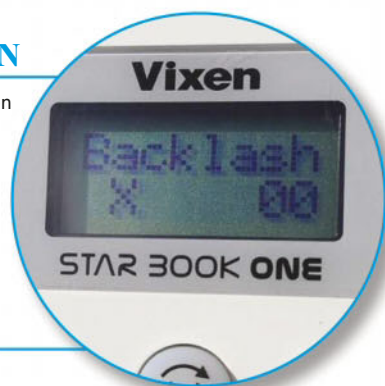
BACKLASH COMPENSATION

Backlash is an effect caused by the small gap between the gears that allow the mount to move. However, when reversing direction in RA, the gap may introduce a perceived delay before the mount appears to respond – this is backlash. A value can be defined in the Star Book One controller to compensate for this.



PERIODIC ERROR CORRECTION

The mount can be periodic error correction (PEC) trained. This involves pointing a telescope fitted with a crosshair eyepiece of 200x or greater magnification at a star, and keeping the star on the crosshair for at least 10 minutes. Adjustments to RA are recorded and used when tracking. PEC data is lost when the mount is turned off.



► The Star Book One controller is a neat and easy to use handset. Its four direction keys allow you to navigate the various menu options, as well as providing facility to adjust the mount's position. As we only had the RA drive module fitted on our review version, only the RA slew buttons lit up on the controller. Standard slewing rates are 0.5x, 1.0x, 8x and 60x sidereal rate, although there's an option to select 'VariSpd', which gives finer adjustment up to 60x should that be required.

Clutch control

The RA and dec. axes both work with friction clutches. If there's a motor unit installed, even with this engaged it's possible to manually slew the mount to another position without problem. Although the clutches work well, we found that they were a bit too stiff to allow us to feel when accurate balance had been achieved during the setup phase. Despite this, the mount seemed happy enough even with a scope close to its load limit.

We performed both visual and photographic tests with the AP-SM mount and were impressed with how it maintained its tracking accuracy even without the autoguider. After an accurate polar alignment with the optional polar alignment scope, we used a high-powered crosshair eyepiece to check the mount's tracking. After two hours, the star was still in the crosshair alignment box.

This is a great mount for grab-and-go wide- and mid-field astrophotography and for a no-nonsense, portable solution it's superb. However, its price

rivals that of some mid-range mounts with far greater load capacities and advanced functions such as Go-To. At the end of the day, it boils down to how much you're prepared to pay for portability.

If this is a very important concern then the AP-SM is a solid choice. **S**

VERDICT

ASSEMBLY	★★★★★
BUILD & DESIGN	★★★★★
EASE OF USE	★★★★★
MOUNT TRACKING ACCURACY	★★★★★
STABILITY	★★★★★
OVERALL	★★★★★

UNIVERSITY OF YORK



The Centre for Lifelong Learning at the University of York has just launched its postgraduate diploma in astronomy, delivered online via distance learning and led by Dr Alex Brown. Bringing together students from across the globe to explore the shared wonder of the night sky, the programme will aim to give students a solid foundation of knowledge which will allow them to undertake their own research. We'll explore radio astronomy through the infra-red and into the visible before travelling to ever-increasing energies of radiation to x-rays and gamma-rays, before concluding with neutrino, cosmic ray and gravity wave astronomy – time will also be spent considering the lives and deaths of stars. This exciting two-year, part-time programme starts in late September every year, and is aimed at home astronomers and the academically inclined. Applications are being taken now.

☎ 01904 328482

www.york.ac.uk/lifelonglearning/astronomy

FIRST light

Baader Morpheus eyepiece series

A new range in varying focal lengths that would suit intermediate observers

WORDS: STEVE RICHARDS

See an interactive 360° model of these eyepieces at www.skyatnightmagazine.com/Morpheus



VITAL STATS

- **Price** £175 each
- **Focal lengths** 4.5mm, 6.5mm, 9.0mm, 12.5mm, 14mm, 17.5mm
- **Apparent FOV** 76°
- **Eye relief** 20mm
- **Optics** Eight elements in five groups
- **Barrel size** 1.25- and 2-inch fit
- **Extras** Belt holster, eyecups, extra dust cap
- **Weight** 323-372g
- **Supplier** David Hinds
- **www.dhinds.co.uk**
- **Tel:** 01525 852696

The introduction of a new range of eyepieces always sends a ripple of excitement through the ranks of observational astronomers, and when the company involved has a reputation like Baader's expectations will be especially heightened. The new Morpheus range includes six focal lengths (4.5mm, 6.5mm, 9mm, 12.5mm, 14mm and 17.5mm) and we had all but the 17.5mm for this review. Each eyepiece is supplied in a sumptuous hinged box, but this isn't just for show – the fact the box is foam-lined means it offers excellent protection for the eyepiece in transit. Each eyepiece is finished in a simple but well applied silk black with chunky rubber grips to ensure that they don't slip out of your grasp.

There are a couple of surprises in store. The first is the unusual ribbed affect on both the 1.25- and 2-inch barrels, referred to as 'safety kerfs' in the technical data supplied by Baader. The second is that the words engraved below the rubber grip – identifying the focal length, apparent field of view and brand name – glow a gentle green-white, although this was very subtle indeed and required absolute darkness to appreciate.

SKY SAYS...

These eyepieces have excellent sharpness over at least 90 per cent of the field of view

Baader's Morpheus eyepieces offer a 76° apparent field of view, 8° wider than its popular Hyperion eyepieces. Comparing the Morpheus eyepieces with their nearest Hyperion equivalents, they are about 11 per cent lighter, and although the field stop was not razor sharp and had a slight hazy blue tint it showed an improvement.

The power of eye relief

The series uses Baader's well-established Phantom multicoatings and these appeared to be very evenly applied. The eyepieces have a generous eye relief of just around 20mm, eye relief being the fixed distance from the curved surface of the outermost lens to the point at which the exit pupil is formed. It is important that your eye should be able to comfortably reach this point to take advantage of the available field of view. This is of particular importance if you wear glasses, as a long eye relief allows you to still enjoy the full field of view while wearing them.

The extendable rubber eyecups were not up to the standard of the rest of the eyepiece in that they were quite flimsy and fell off nearly every time they were deployed, which was rather a

TYRE TECH GIVES EXTRA GRIP IN THE TELESCOPE

Eyepiece and focuser manufacturers have long been aware of the risks of eyepieces slipping out of their holders and various designs have been adopted to reduce the chances of this happening. The original single bolt clamping method was improved by the addition of wide undercuts in the eyepiece barrel that acted as a détoné if the bolt became loose.

However, none of us appreciate the score marks left in our eyepiece barrels by the bolts so manufacturers usually install brass compression rings inside the eyepiece holder that grip the eyepiece barrel when the securing bolt is tightened. This system works very well but the undercut and the position of the compression ring don't always align correctly and in the worse

cases, can result in an eyepiece becoming jammed in the focuser. Baader has devised a unique solution by machining multiple grooves encircling each barrel every 2mm. The company calls these 'Safety Kerfs', and they are reminiscent of the longitudinal slits cut in road tyres, which share the same name and are designed for increased grip. We found these kerfs worked extremely well.



M43 ADAPTOR THREAD

Substantial eyepieces like these are ideal for afocal imaging. Removing the rubber eyecup reveals a male M43 thread that can be used with an adaptor (not included) to attach a camera directly to the eyepiece.

RUBBER GRIP

It is every astronomer's fear that they will drop an eyepiece when installing or removing it from their focuser or star diagonal. The chunky waffle-ribbed design of the rubber grip surrounding the Morpheus eyepieces gives plenty of confidence when handling them, even with a gloved hand in the cold of night.



1.25- AND 2-INCH BARRELS

The Morpheus design incorporates both 1.25- and 2-inch eyepiece barrels, which allow them to be used in a range of focusers and star diagonals. The 1.25-inch barrel has a standard filter thread built-in, which serves the eyepiece well when used in either a 1.25- or 2-inch eyepiece holder.

BELT HOLSTER

Removing the padded interior of the box the eyepiece arrives in reveals a set of accessories. These include a rather sensible and practical belt pouch that holds eyepiece securely when not in use yet keeps it accessible. The pouch fits simply to a belt and fastens with a Velcro fastening.



FIRST light

SKY SAYS...

Now add these:

1. Baader Optical Wonder fluid
2. Baader Optical Wonder cloth
3. Hyperion digital T-ring adaptor

► disappointment. Baader does include a second dust cap tailored to fit the eyecup in the extended position which does help to alleviate this issue.

We tested the eyepieces using a Sky-Watcher 250PX Newtonian and William Optics FLT 98 apo refractor with focal ratios of f/4.7 and f/6.3 respectively. Contrast, sharpness and colour were excellent when observing a range of stars and star clusters, with the beautiful colour contrasting pair of Albireo looking spectacular through the refractor. Examining brighter stars for consistent focus as they drifted across the field of view demonstrated that the field was very flat and certainly better than the equivalent Hyperions.

We found excellent sharpness over at least 90 per cent of the field of view, although as we approached the extreme edges a tiny amount of lateral colour, also known as colour fringing, started to become apparent. The eyepieces were pretty consistent here although we did feel that the 14mm version displayed slightly more lateral colour than the others. The eyepieces were very close to parfocal with just $\pm 88\mu\text{m}$ maximum variance, making it easy to swap from one focal length to another without having to tweak the focus too much, and each one afforded us an enjoyable and immersive experience.

We enjoyed the crisp views delivered by the Morpheus eyepieces and would certainly recommend them to intermediate observers as they produce wonderful views at a sensible price. **S**



TWO EYECUPS

The eyepieces are supplied with two types of fold-up eyecup, a standard circular one and a winged version that helps to reduce unwanted light intrusion from the side. These cups are made from soft rubber, making them comfortable to use, but they were rather flimsy and often fell off during deployment.

VERDICT

BUILD & DESIGN	★★★★★
EASE OF USE	★★★★★
EXTRAS	★★★★★
EYE RELIEF	★★★★★
OPTICS	★★★★★
OVERALL	★★★★★





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Joe,
"Fast and efficient. I thoroughly recommend them.
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one buyer to deal with....simple, speedy and safe"



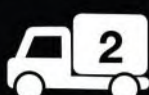
Ron,
"Their service was first class and I am extremely
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Books

New astronomy and space titles reviewed

RATINGS

- ★★★★★ Outstanding
 ★★★★★ Good
 ★★★☆☆ Average
 ★★☆☆☆ Poor
 ★☆☆☆☆ Avoid

Cosmonauts

Edited by Doug Millard
 Scala Publishers
 £45 • HB

**BOOK
OF THE
MONTH**



To contemporaries, the fact that the Soviet Union had pioneered space exploration sounded almost as fantastic as the possibility of space travel itself. In the following decades, as the US regained momentum in the Space Race and the USSR itself disappeared from the map, the story of the early Space Age got somewhat blurred in the public imagination. This beautifully illustrated hardcover volume called *Cosmonauts* – and its associated exhibit at the Science Museum in London – both aim to relive the glory days of the Soviet space programme and rekindle the spirit of the Russian space programme.

The book opens with an exploration of the little known but crucial roots of the Soviet space dream, extending to pre-revolutionary Russia and into the 19th Century. The author gives a rare due for the Soviet space achievements to Western writers such as Camille Flammarion and Jules Verne, who inspired an early generation of Soviet rocketeers. It also explores and illustrates how the fields of art and science, seemingly unrelated and often conflicting, interacted.

The story then offers unique perspectives from several authors with personal connections to space flight giants, including Sergei Korolev's daughter and Konstantin Tsiolkovsky's great-granddaughter, who dedicated their lives to preserving the legacies of their famous relatives.

Jumping several decades into the future, we learn about some of the most dramatic and harrowing episodes in the history of the Russian space programme from those who lived to tell the tale: the revival of the dead and frozen Salyut-7 space station in 1985, as recalled by the Russian cosmonaut Vladimir

Dzhanibekov, and the near-fatal fire on the Mir space station in 1997, as remembered by cosmonaut Aleksandr Lazutkin.

Finally, the book provides a rare glimpse into the past and present of the Russian space industry, exemplified by its iconic space centres: the cosmonaut training facility in Star City, the Zvezda spacesuit factory in Tomilino and the Institute of Medical and Biological Problems in Moscow.

All chapters are accompanied by colorful photos of some of the historic and rarely seen artifacts on display as part of the *Cosmonauts* exhibition.

★★★★★

ANATOLY ZAK is a space journalist and author of *Russia in Space: the Past Explained, the Future Explored*



Alexei Leonov's *Over the Black Sea* painting marks his first spacewalk



TWO MINUTES WITH DOUG MILLARD

How did you go about condensing 70 years of history into one volume?

We didn't: it would require several volumes to do the story justice! We thought about the periods in time covered by the exhibition and picked key events and people that could represent those periods. We wanted to present a 'human' foil to the amazing Space Age technologies that are in the exhibition.

Why is it important to tell the Russian side of the space story?

The Soviet space programme was shrouded in secrecy due to its inseparable military connections and organisation. Then, with Apollo's triumphant Moon landing in 1969, much of what the Soviets had achieved was blotted from memory. For the Science Museum it had also been more difficult to display real Soviet and Russian space technologies than it was the European and American equivalents. The galleries therefore underplayed the Soviet and Russian achievements.

How did you go about representing the spirit of the exhibition in the book?

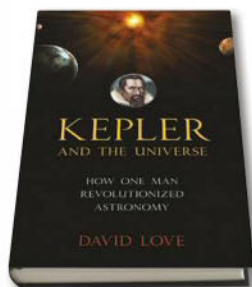
The exhibition is a story of Russian technological development, but it is also a story of Russia in the 20th Century, from the imperial years through to modern times. It is also an observation on humanity's relationship with space and how that might evolve in the future. The book echoes all of these themes, but above all it is an account of Russian people – some famous, others less so – who opened a road to the stars.

DOUG MILLARD is senior curator of the *Cosmonauts: Birth of the Space Age* exhibition at the Science Museum London

Kepler and the Universe

How One Man Revolutionised Astronomy

David Love
Prometheus Books
£19.99 • HB



Johannes Kepler, best known for his laws of planetary motion, came to astronomy at a pivotal moment in history. He was one of the last astronomers to

have also been an astrologer, yet one of the first to support the Copernican Sun-centred model of the Universe. David Love's very readable book brings this world to life, never shying away from the technical details of Kepler's work, what it built on, and where it would later lead.

The book is set out as a geographical and chronological journey through Kepler's life and work. We see him grow up, move

to Graz, spend time in Prague with Tycho Brahe and then move to Linz. His family are minor characters: there is a nice quote about his first wife after she died, many of his children died in infancy and his mother's trial for witchcraft is also covered. Mainly, however, the book is about his work, his working relationships and the religious disputes that dominated Europe, impacting on his life, his views and his research.

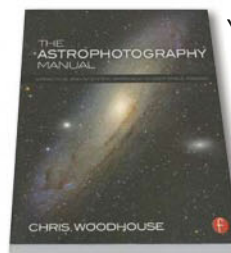
David Love is a good storyteller: through Kepler's story we get a strong sense of the science, the religious atmosphere and the ways in which contemporary astronomers and philosophers interacted and corresponded. If I have one criticism, it is that I felt he was unnecessarily dismissive of Islamic and Arabic science in the period between the Ancient Greeks and Copernicus. Other than that, I found this book to be an excellently readable introduction to the man, the historical period and his contribution to astronomy.

★★★★★

DR EMILY WINTERBURN is the author of *Stargazer's Guide*

The Astrophotography Manual

Chris Woodhouse
Focal Press
£31.99 • PB



You've been taking deep sky photos for a while, they're reasonable, but you want to progress to a higher level. What's your next step? The stated

goal of *The Astrophotography Manual* is to help fast track you to intermediate astrophotography, so it might be worthy of your consideration.

This comprehensive and well-illustrated 280-page manual will, with good humour and detailed discussion, help avoid many of the pitfalls of more advanced deep-sky imaging, and it is clear that author Chris Woodhouse has masses of personal knowledge on this subject. He guides you from the basics of astronomy, optics and imaging, through equipment and set-up, on to optimising camera settings and sections on focusing and autoguiding. The latter half is devoted to explaining image-processing techniques, particularly using PixInsight, MaximDL and Photoshop. The book ends on a high with Woodhouse walking through several real imaging and processing sessions, each one for a different deep-sky object.

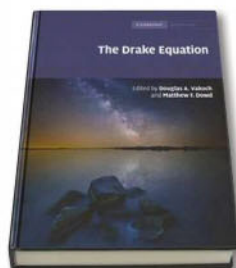
It is not an easy read, but that is due to the technical nature of the subject rather than the writing, which is clear and logical. It is a great reference book to dip into, to read and re-read sections of interest. My only gripe is the inclusion of several references to planetary imaging in what is primarily a manual for deep-sky imagers. This would be better dealt with separately. That aside, I can thoroughly recommend this original book for those who want to make progress in their quest for improved deep-sky imaging.

★★★★★

MARTIN LEWIS is an astronomer and a regular BBC Sky at Night Magazine contributor

The Drake Equation

Edited by Douglas A Vakoch
and Matthew F Dowd
Cambridge University Press
£99.99 • HB



Will we ever communicate with alien civilisations? No one knows, but this book provides the best available information to estimate our chances

of success. And the good news is that a lot of progress has been made in all the relevant fields of science since 1961, when American radio astronomer Frank Drake came up with his famous equation to 'calculate' the number of communicating extraterrestrial species.

Professional historians, astronomers and biologists describe every single term in *The Drake Equation* (like the frequency of planet-hosting stars, or the fraction of life-bearing planets where intelligence

develops), both from a pre-1961 and a post-1961 perspective. As a result, the book provides an entertaining mix of obsolete historical ideas and recent scientific insights.

Today, we know much more about the abundance of habitable planets, mainly thanks to NASA's Kepler space telescope. But our ideas about the origin of life and the evolution of intelligence are still as murky as they were half a century ago. As a result, we still don't have a clue about the prospects for SETI (the Search for Extra-Terrestrial Intelligence).

Life may or may not be ubiquitous in the Universe, but, as neuroscientist Lori Marino writes: "There is no evidence for any progressive linear trends in biological evolution that lead to humans." Or to alien intelligence, for that matter. Then again, we live in a very big Universe.

The Drake Equation is not an easy read, but it's a treasure trove of information on one of the grandest questions of all time: 'Are we alone?'

★★★★★

GOVERT SCHILLING is an astronomy writer and author

Gear

Elizabeth Pearson rounds up the latest astronomical accessories



1

1 Galileo Moon Phase Clock

Price £49.95 • Supplier Curious Minds
01436 670806 • www.curiousminds.co.uk

Track the phases of the Moon over its 29.5-day cycle with this clock. The bottom half houses a normal clock to help let you work out the best time to observe the Moon.

2 Green Clean LC-1000 Silky Liquid and Wipe

Price £8.90 • Supplier 365 Astronomy
020 3384 5187 • www.365astronomy.com

Keep your optics clean with this product, which lifts surface grime and leaves a dirt repellent without affecting light transmission.



2

3 Meade Series 4000 1.25-inch Eyepiece and Filter Set

Price £199 • Supplier Telescope House
01342 837098 • www.telescopehouse.com

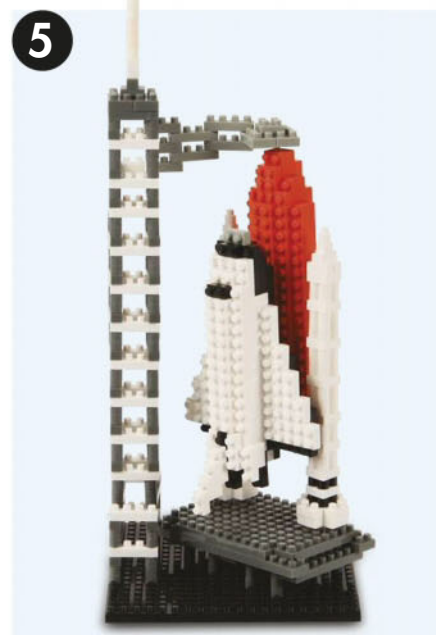
This set contains five Plössl 1.25-inch eyepieces, seven filters and two 'shorty' type Barlow lenses in an aluminium carrying case.

4 Orion Tapered 2-inch to T-thread adaptor

Price £39 • Supplier SCS Astro
01823 665510 • www.scsastro.co.uk
Securely attach your DSLR or CCD camera in a 2-inch eyepiece holder with this adaptor. The unique tapered design ensures your camera stays in place even if the collar comes loose.



4



5

5 Nanoblock Space Centre

Price £16.99 • Supplier IWOOT
www.iwantoneofthose.com

Release your inner rocket scientist (and child) with this 580-block kit of a space shuttle and launch pad.



3

6 Fotomate H-26QR Tripod Ball Head

Price £25 • Supplier The Binocular Shop
www.binocularshop.com

Easily mounted to any standard tripod, this ball head allows you to move your equipment to any angle while remaining safe and secure. It can carry a load up to 3.5kg.



6



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WHAT I REALLY WANT TO KNOW IS...

Why do galaxies stop making stars?



Grant Tremblay is questioning why starbursts are not occurring at a much greater rate in giant elliptical galaxies

INTERVIEWED BY PAUL SUTHERLAND

The Universe's largest galaxies have been seen to be forming clumps of hot blue stars along the jets from the supermassive black holes at their centres. But observations with the Hubble Space Telescope show the rate of formation is much lower than one might expect.

These galaxies are called ellipticals. They are much more massive than our own Milky Way and sit in huge, hot halos of gas that act like cosmic rain clouds. These clouds should be dumping huge amounts of cooling material into the galaxies to form new starbursts, but they are not. Something is clearly stopping the gas from cooling.

Elliptical galaxies are the product of the merger of a number of other galaxies – when our Galaxy collides with the Andromeda Galaxy in the far future, they will develop a more elliptical shape and become much more massive. Typically elliptical galaxies are 'red and dead', meaning that they have much older stellar populations, and much less ongoing star formation.

Fuel without the fire

Stars are hot, but they form from the gravitational collapse of clouds of cold molecular gas, the coldest densest material found in galaxies. The most massive galaxies generally reside at the heart of rich clusters – the most massive gravitationally bound objects in the Universe. Very hot gas surrounds these galaxies in a ball over a million light-years wide, and the gas is so hot and so dense that it cools rapidly, over about 500 million years, as it rains down. A monsoon of cooling gas should be collapsing into the central galaxy in the cluster, providing enormous fuel for star formation – 1,000 solar masses a year – and powering huge reservoirs of cold molecular gas. But the gas cools at about 10 per cent of the rate that you might expect.

When you dump a lot of gas into a massive galaxy, it simultaneously sows the seeds of its own

growth and its own destruction. Some of this gas will form stars and grow the galaxy, but some will eventually fall into the centre of the galaxy and onto the supermassive black hole.

And if you dump gas onto a supermassive black hole, you have to liberate the energy produced.

In the galaxies I work on, the energy liberated by black hole growth is about equivalent to one trillion trillion atomic bombs per second being radiated outwards. The black holes launch jets close to the speed of light.

With colleagues, I used data from the Chandra X-ray Observatory to examine the ball of hot gas, Hubble to observe the cooling gas and stars forming within it and ALMA in Chile to see the cold molecular gas itself.

What we are finding is that, weirdly, the jets from the black holes might simultaneously inhibit and trigger star

formation. That sounds crazy, but we think that they act in a similar way to the thermostat in your house, regulating in a feedback loop, so if you turn up the cooling rate from the hot atmosphere, you'll turn up the heating rate – which will then lower the cooling rate, which will in turn then lower the heating rate. Within these violently energetic jet events, something really subtle and elegant is happening.

We don't really have the answer to what that is yet. And as astronomers find so often in the Universe, when you think you have an answer it just opens up many more questions. One problem with this feedback model is how the energy prevents the hot gas from cooling. It is a bit like trying to heat a large house with a blowtorch. The flame may be very hot, but if its heat isn't spatially distributed throughout your house, it's going to be a lousy heating system.

I think ALMA will be key to helping explain this mystery because the cold phase of the feedback from the black hole is the most unexplored part. We haven't had the technology to do it until recently, but hopefully ALMA can look at the 'puddle' that the cosmic rain creates and complete the picture. **S**



Elliptical galaxies like NGC 1132 form when smaller galaxies merge; this is what will happen to the Milky Way in around four billion years' time

ABOUT GRANT TREMBLAY

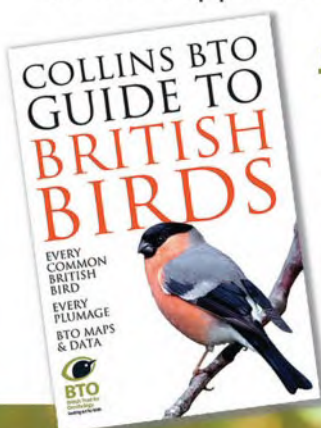
Dr Grant Tremblay is an observational astronomer and NASA Einstein Fellow at Yale University, where he harnesses the most powerful telescopes on Earth and in space to learn about star formation.



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The Southern Hemisphere in November



With Glenn Dawes

WHEN TO USE THIS CHART

1 NOV AT 00:00 UT
15 NOV AT 23:00 UT
30 NOV AT 22:00 UT

The chart accurately matches the sky on the dates and times shown. The sky is different at other times as stars crossing it set four minutes earlier each night. We've drawn the chart for latitude -35° south.

NOVEMBER HIGHLIGHTS

Dwarf planet Pluto has always been a challenge, but it's currently residing in star-rich Sagittarius, making it a real needle in a haystack. However, the 14th-magnitude planet is easier to find early in November as it passes close to mag. +3.5 Ξ^2 (ξ^2) Sagittarii. Pluto starts the month 20 arcminutes west of the star, with closest approach on the 17th only 1 arcminute to the north. Sketch or image the field a few days apart to see Pluto's motion. As the planet sets around 23:30 EST you need to get onto it promptly.

STARS AND CONSTELLATIONS

The spring and summer evenings offer southern hemisphere observers a view of the Local Group of galaxies. Besides the Milky Way, the next three brightest members are clearly visible to the naked eye under dark skies: the Small and Large Magellanic Clouds are high in the south and southeast respectively, and low in the north dwells the Andromeda Galaxy, M31. Using binoculars you can add NGC 253 in Sculptor (passing overhead) and M31 in Triangulum, near to M31.

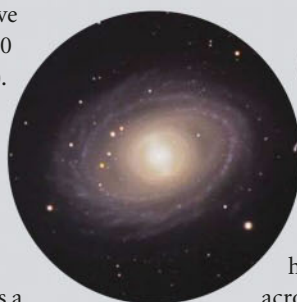
THE PLANETS

Saturn can be seen early in the month, low in the twilight sky. By mid-month the evening sky has no bright planets, leaving only Uranus and Neptune. Early in the month the pre-dawn sky sees Jupiter's rising quickly followed by Venus and Mars. They

are best observed around 04:00 EST, an hour before dawn. As Mars climbs into the sky it overtakes Venus. The pair are at their closest on the 3rd, separated by only 0.7° . By month end, Jupiter is visible in the morning sky at around 02:00 EST.

DEEP-SKY OBJECTS

The barren constellation of Fornax is best known for its galaxies but is also home to an impressive planetary nebula, NGC 1360 (RA 3h 33.2m, dec. $-25^\circ 52'$). Located 4° south of mag. +4.3 τ^4 (Eridani), it also forms an equilateral triangle with this star and mag. +5.2 τ^7 (Eridani). At 50x magnification the mag. +9.6 nebula appears as a haze around its mag. +11.3 central



star. A large scope and an OIII filter will reveal its oval shape and a dark region.

A short hop 1.3° east-southeast from NGC 1360 will take you mag. +9.7 spiral galaxy NGC 1398 (RA 3h 38.9m, dec. $-26^\circ 20'$; pictured). It appears as a slightly oval haze around 1.5 arcminutes across that gradually brightens towards its star-like nucleus.

CHART KEY

GALAXY
 OPEN CLUSTER
 GLOBULAR CLUSTER
 PLANETARY NEBULA

DIFFUSE NEBULOSITY
 DOUBLE STAR
 VARIABLE STAR
 COMET TRACK

ASTEROID TRACK
 METEOR RADIANT
 QUASAR
 PLANET

STAR BRIGHTNESS:
 MAG. 0 & BRIGHTER
 MAG. +1
 MAG. +2
 MAG. +3
 MAG. +4 & FAINTER

